ELECTRICAL ENGINEERING

JUNE 1950

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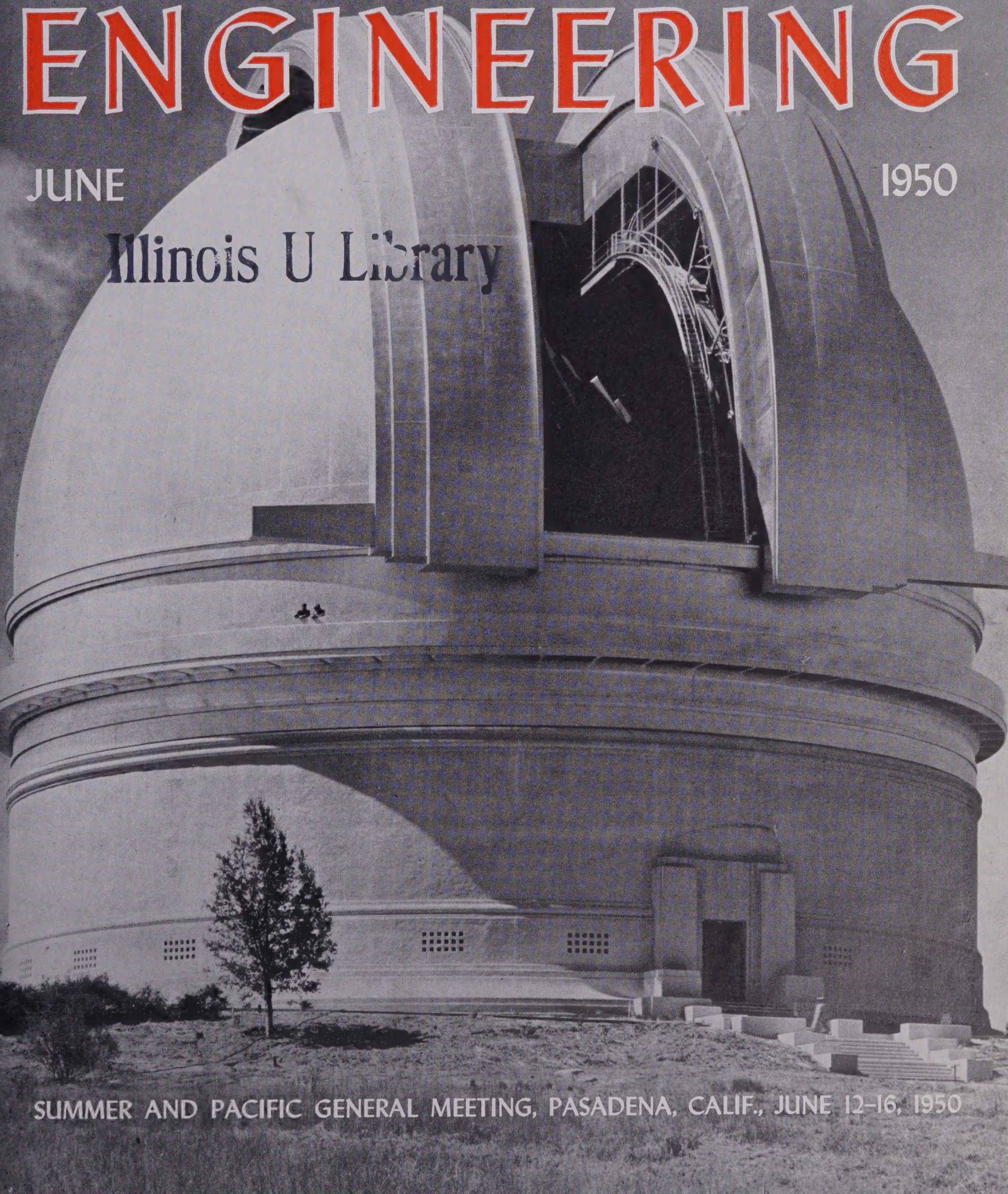

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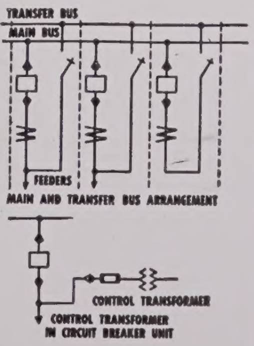
VARIED CIRCUIT ARRANGEMENTS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Unique compartment design permits many circuit arrangements in a standard breaker unit. Two typical arrangements are shown:

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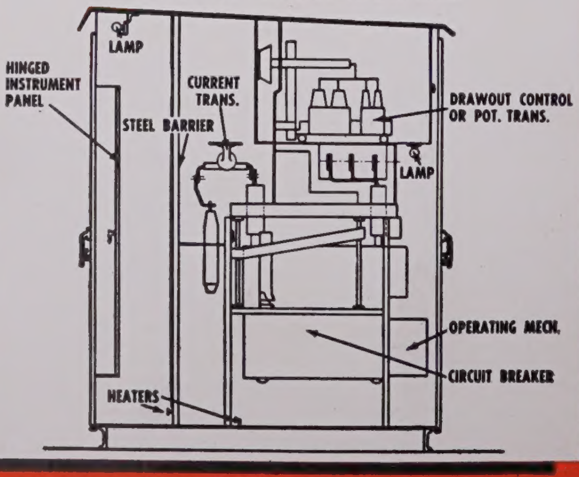

ELECTRICAL ENGINEERING

Registered United States Patent Office

JUNE
1950

The Cover: California's Mt. Palomar structure housing the 200-inch telescope, the world's largest (Two men can be seen on the balcony, center left.) A special all-day trip to the Mt. Palomar Observatory has been arranged for visitors to the AIEE Summer and Pacific General Meeting in nearby Pasadena.

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we'll take the "Red Ink" out of your motor repair shop

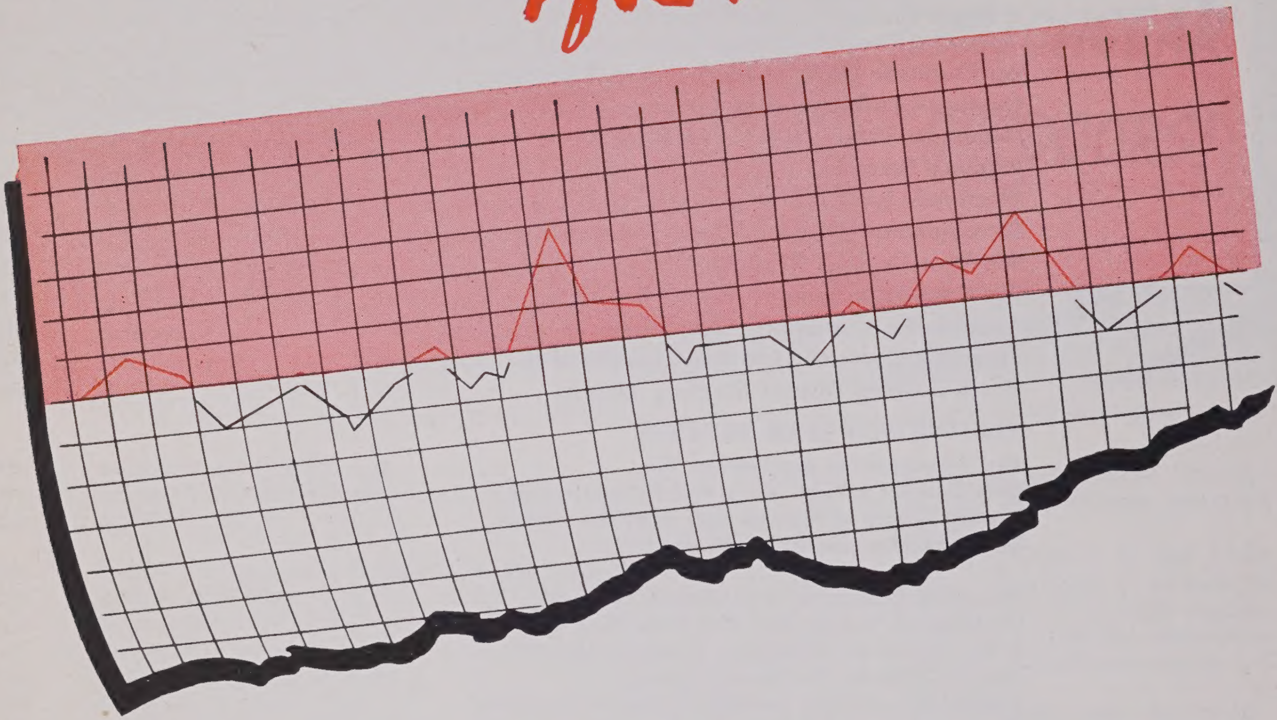

Chart the week-to-week demand and the week-to-week costs of your motor maintenance-repair shop and you'll find that the red ink is concentrated at the periods of peak demand. Normally, the shop probably operates efficiently. But the peak demands cost overtime, and rushed, slighted work. To overcome that condition you'd have to over-equip and over-man your shop. And that means higher cost every day. Many industrialists and generating plants, on the other hand, are operating such shops with very high efficiency. They are equipped and manned to handle the normal demand; they turn over the peaks — the red ink jobs — to us. Thus they avoid the vicious circle of excessive labor costs and excessive overhead. They get work, too, comparable to the best they can do themselves. We've done so much industrial and electrical utility work we know how; we're efficient; our costs are low. That means *your* costs are low, both in your shop and in ours. Our engineers will be glad to come to your office to suggest experienced ways and means of taking the top costs out of *your* motor and generator work. Just drop us a line for quick action.

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ELECTRICAL ENGINEERS: MAKERS OF ELECTRICAL COILS AND INSULATION—REDESIGNING AND REPAIRING OF ROTATING ELECTRICAL MACHINES

TRADE MARK

HIGHLIGHTS........

District Paper Digests. Brief authors' digests of District papers presented at the AIEE North Eastern District Meeting, which was held in Providence, R. I., April 26–28, are included in this issue. These papers are not scheduled for publication as *Proceedings* (*pages 553–4*).

To the Student Members. This month, President Fairman directs his remarks primarily to the Student members of the Institute—offering them, as members of the engineering profession, ideas for debate and consideration (*pages 483–4*).

An Engineer Looks at Mathematics. We all need mathematics; to the scientist and the engineer mathematical concepts are essential for the expression of scientific phenomena. Thus, the great importance of their part in training young engineers was pointed out by AIEE Past President Lee to the National Council of Teachers of Mathematics in an address which is published in this issue (*pages 492–5*).

Electronic Synchronous Speed Regulator. To keep the frequency of an alternator output voltage in synchronism with a frequency source of low power, a speed regulator for the driving d-c motor has been designed. A voltage proportional to the phase angle between the two voltages is applied to the field circuit of the d-c motor, and regulation of the motor speed is accomplished in this manner (*pages 532–7*).

Useful Power From Nuclear Fission. A description of the progress to date in the utilization of nuclear fission for useful power is given in an article by Dr. C. G. Suits, the director of research of the General Electric Company. Dr. Suits describes some of the plants being built for research in this field and tells the type of work that must yet be done before nuclear fission can be considered a reliable and predictable power source (*pages 523–8*).

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Electronic Excitation and Regulation of Generators. Superior to rotating excitation units for generators in many ways are the recently perfected electronic exciters. The electronic type has a wide operating range; it can operate at very light loads or severe overloads for long periods of time without damage, and it allows the generators to be paralleled simply and without danger of feedback. Maintenance can be done on the electronic exciters without affecting the generated output in any way (*pages 518–20*).

Gaseous-Conduction Phenomena. The first article in a series of four on gaseous-conduction phenomena has been written by J. D. Cobine of the General Electric Research Laboratory. This article gives a survey of the field and describes the basic theory behind the non-self-sustaining discharges and those which are self-sustaining. Equipments using the two types of discharge are described, and figures are quoted to indicate the value of such equipment manufactured each year (*pages 499–504*).

500-Kv Test Project. Tests which have been run on the high-voltage test lines of the American Gas and Electric Service Corporation are described and discussed this month by Philip Sporn and A. C. Monteith. The effects of conductor surface and weather on corona loss are shown, and the importance of foul weather in determining the economic aspects of corona loss are noted. Extensive tests also have been made of the effects of corona upon radio communication service (*pages 506–11*).

Magnetic Cores. Magnetic cores of thin insulated tape are being used extensively in modern communication systems. These tapes are insulated by a cataphoresis process before the cores are formed, so each lamination must be protected against interlaminar welding during the final heat treatment. A description of the complete process and the equipment used is given in this month's magazine (*pages 544–8*).

Application of Magnetic Amplifiers. Magnetic amplifiers are now being used as components in many types of control and regulating circuits. They have been used as photoelectric-cell amplifiers, as sensitive relays, as frequency regulators for d-c to a-c motor-generator sets, and in numerous other applications (*pages 538–43*).

Sensitive Ground Protection. A report compiled by a Project Committee of the AIEE Relay Committee summarizes present-day practices in sensitive ground protection of 3-phase systems and also indicates where improvements are desirable or necessary. Sensitive ground protection as considered comprises relaying of ground faults with fault currents to ground of a magnitude in the order of about one per cent of the normal of full-load current of the feeder (*pages 528–30*).

Centralized Instrumentation. A recent conference on the centralization of instrumentation and controls in steam power stations included papers and discussions on the subject. Advantages and disadvantages of the system are presented, and descriptions of station using this type of control are given (*pages 485–92*).

Primary Batteries. Two important problems confronting the designer of a dry battery for military use are to develop a battery capable of operation over a wide temperature range and to make the battery reliable after long storage periods. These problems must be worked out with the additional factor of keeping the size of the battery to a minimum (*pages 515–18*).

Correction. In the article "Regulation of A-C Generators With Suddenly Applied Loads" by E. L. Harder, R. C. Cheek, and J. M. Clayton (*EE, May '50, pp 391–5*), Figures 3 and 6 were arranged so that graphs with like generator open-circuit time constants were grouped together. For easier use and interpolation the figures should be arranged with graphs of like exciter response grouped together in the order of ascending time constants. The figures will be arranged in this more convenient manner in AIEE *Transactions* and AIEE *Proceedings.*

AIEE Proceedings

Order forms for current AIEE *Proceedings* have been published in *Electrical Engineering* as listed below. Each section of AIEE *Proceedings* contains the full, formal text of a technical program paper, including discussion, if any, as it will appear in the annual volume of AIEE *Transactions.*

AIEE *Proceedings* are an interim membership service, issued in accordance with the revised publication policy that became effective January 1947 (*EE, Dec '46, pp 567–8; Jan '47, pp 82–3*). They are available to AIEE Student members, Associates, Members, and Fellows only.

All technical papers issued as AIEE *Proceedings* will appear in *Electrical Engineering* in abbreviated form.

Location of Order Forms	Meetings Covered
Dec '48, p 35A	Midwest General Southern District
Apr '49, p 25A	Winter General (1949)
Jul '49, p 47A	South West District Summer General
Nov '49, p 51A	Pacific General Fall General
Feb '50, p 46A	Winter General (1950)

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This picture was taken in the Bridgeport office of The Southern New England Telephone Company, one of the 22 operating telephone companies which the Laboratories serve through the Bell System.

Cutting Board for Telephone Costs

Few of these tools have sharp edges. But they are powerful cost cutters. Whenever a telephone craftsman reaches for one, he finds the right tool ready to his hand. There's no time wasted trying to do a complicated job with makeshift equipment.

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Keeping the telephone tool kit abreast of improvements is a continuing job for Bell Telephone Laboratories. It's another example of how the Laboratories help keep the value of your telephone service high, the cost low.

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To Our Student Members
(and Others Who May Wonder What the President Is Up To)

JAMES F. FAIRMAN
PRESIDENT AIEE

IT IS with some trepidation that I address these remarks to the Student members of the Institute. Just a short time ago I listened to a lively and somewhat critical discussion among a group of undergraduates of the talks to which they had been exposed by a number of individuals whom I considered to be outstanding in their respective fields of public service. I wondered with more than a trace of uneasiness what was said by those students who had enjoyed the privilege of listening to me on a number of occasions in commenting subsequently upon my sage remarks as well as upon my age, mannerisms, personality, and motives. But that is one of the hazards of being President of the Institute and the critical point of view is by no means peculiar to our younger members.

Lest I be misunderstood, let me hasten to say that I am heartily in favor of objective and constructive criticism. It makes for progress. It is good mental exercise. And it can be good fun.

Here are a few ideas for you to debate among yourselves and to arrive at your own conclusions as to their merits.

YOU AND THE INSTITUTE

THERE would be no point in addressing these words to you if I did not believe that you need to be a member of at least one society such as the AIEE organized for the purpose of advancing the theory and practice of that field of engineering in which you intend to work. For your own professional growth and development you need the information contained in the Institute's publications and the contacts with your contemporaries and your elders which are afforded by its meetings and committee work. To obtain these benefits you must exert yourself, you must read intelligently, you must listen attentively, you must think clearly, you must make your own contribution to the discussions, and you must participate actively in the work of the local unit (Branch or Section) of which you are a member.

You must also pay dues to keep the organization running. Since this is the item about which you sometimes have doubts, let me suggest that the aggregate dues payments to the Institute during a lifetime are a relatively minor item compared to your investment in your technical education. Roughly they are equivalent to the total cost of one semester in college. The benefits are vastly greater than one semester and are especially significant during the early years of your professional life. What will you get out of it? In my opinion, you will get out of membership in the Institute just what you put into it plus a portion of what others put into it.

Any worth-while voluntary membership organization is a mutual benefit affair and so just as I believe you need the Institute, I believe the Institute needs you if it is to continue to do its job. It needs the strength and enthusiasm of youth. It needs new courage and fresh viewpoints. It needs a continuous crop of new workers and new leaders. Its field is constantly expanding at a rate dependent solely upon the will of its members. Its opportunities for service to its members and to society are unlimited.

Wherever you may be located when you leave school and get a job, go to the local Section meetings, find out how the work is organized, and volunteer for service in whatever activity interests you, or whatever activity seems to need your help. Don't wait to be asked. You probably won't be. Volunteer.

YOU AND REGISTRATION

I HOPE that you have heard that all the 48 states have laws licensing the practice of professional engineering. I hope you have heard enough about the subject to convince you of the desirability of obtaining your license at the earliest opportunity. Space does not permit me to go into the matter in detail but an inquiry addressed to Institute headquarters will be answered promptly.

The subject has been debated endlessly. My hope is that the coming generation of engineers will handle the problem more wisely than did their predecessors. But professional licensing is one of the facts of life today and it behooves you, as members of the engineering profession, to help make it what it should be—an instrument for raising the standards of the profession and thereby affording real protection to the public whom we serve.

The first step, naturally, is to obtain your own license to practice. The next step is to work through organizations of engineers for better and more uniform licensing laws.

YOU AND DEMOCRACY

MAYBE you know what Democracy is. I hope you do, and that you think it is worth defending.

To me, Democracy implies that each of us to the full extent of his time and ability, and taking into account his special talents, does his share in promoting the common welfare of every group of which he is a part or with which he is connected directly or indirectly. To me, Democracy, like charity, literally begins at home. It begins in the family group, the school, the college, the Student Branch

---

James F. Fairman is Vice-President, Consolidated Edison Company of New York, Inc., New York, N. Y.

James F. Fairman

and the Section of the Institute, the fraternal organization, the club, the various civic and charitable organizations, the church, and in all the other organized activities of a community. If, working together, we can make a success of such activities, it should be easy to make Democracy work in the broader fields of state and national affairs; yes, even in the very broad field of international affairs. If we can't or won't, then in my opinion we shall lose this thing called Democracy and we shall deserve to lose it.

If I am anywhere near right in this, my understanding of Democracy and the democratic process, I believe we have not far to go to find the reason for our present fears that our democratic system is in danger. We and many other people have not been working at it. We have largely "left it to George," and George has been a very busy man. Being busy, he had to take some short cuts. Also, since nobody stopped him, he has been trying out some ideas of his own and naturally enough, they were principally directed to the greater glory of George. We can't blame George. He probably did the best he could. Unfortunately, we don't like the results and certainly we don't like George as well as we did.

I think we have been lazy in passing the buck to George on important matters of public interest. I think we should actively carry our own individual and definite responsibilities of citizenship.

Are you fellows going to play golf on Election Day, all day, as so many of your elders have done, in the mistaken and lazy belief that "one vote more or less won't make any difference to anybody?" Are you going to crab about how the Institute is run, and do nothing about it but crab? Are you going to stay away from church, asserting that it is full of hypocrites who would taint your pure souls? Are you—but why go on? You have to make your own answers, and you will have to live with the consequences of your action or inaction.

YOU AND ETHICS

SOME time ago the editor of *Electrical Engineering* asked me to review two papers, each presented by a distinguished member of the Institute before his Section. The two Sections are well separated geographically, but the authors are poles apart in philosophy. Both papers were well written. But the thing that startled me was the radically different conclusions which were reached by these two distinguished gentlemen, although starting with substantially the same facts.

What is wrong with our engineering processes when that can happen? I was brought up to believe, as an engineer—and I suppose your professors still so teach you—that if all the facts are in our possession, we should be able to reason to a sound and logical conclusion, and that generally only one real answer is possible. Of course, sometimes in mathematical processes the answers can be negative or imaginary, and in such instances you know how to interpret them or what to do with them. Apparently, in the case of these authors, the imaginary answers had too strong an appeal entirely to be resisted. Consequently, their conclusions were colored accordingly and very beautifully colored too. But that's not the engineering process, that's the kind of special pleading that all too frequently characterizes political and other aspects of human affairs. As engineers, let's leave such specious special pleading to others. Let's content ourselves with being honest.

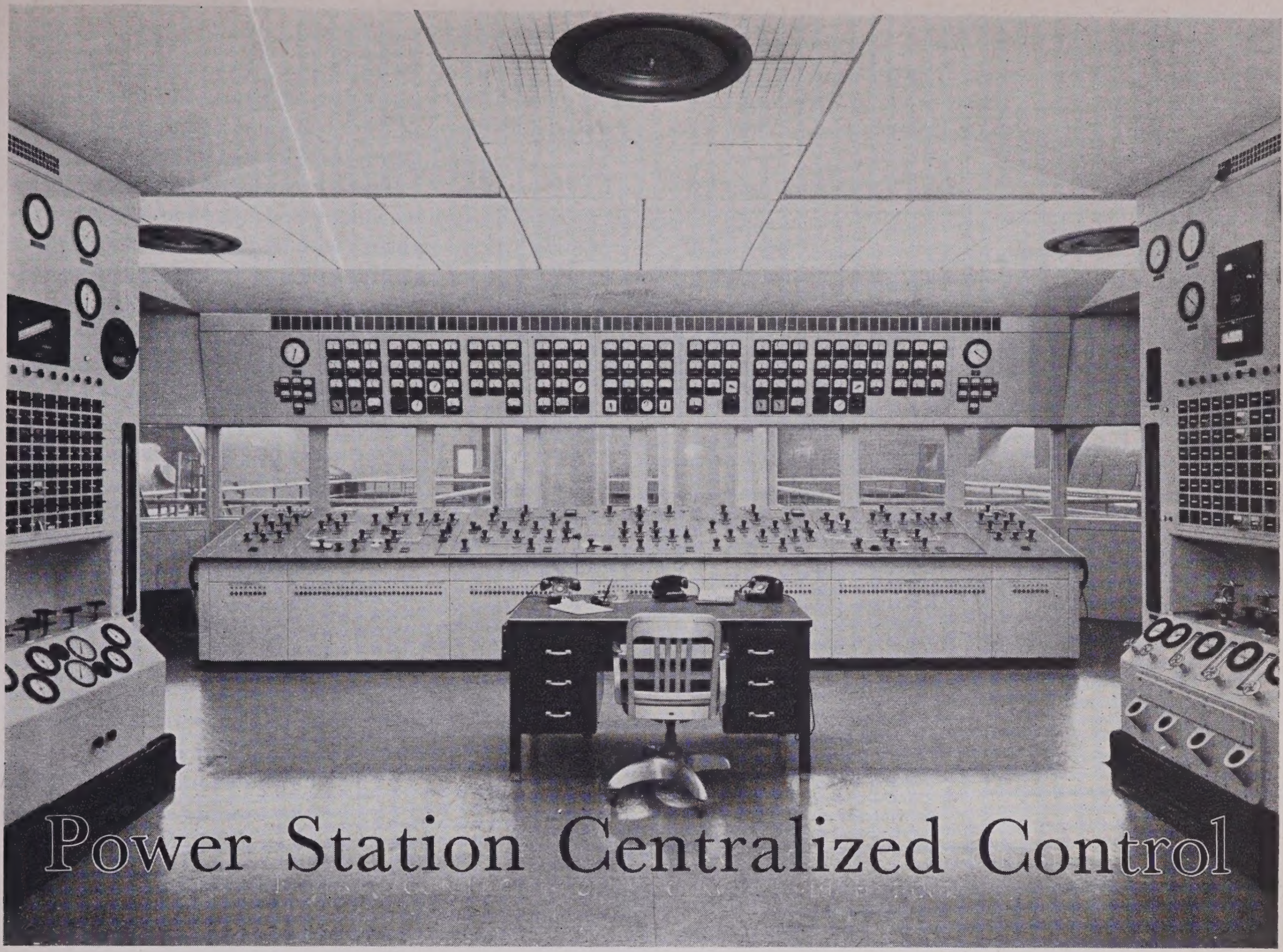
After reading those papers, I looked up our Code of Principles of Professional Conduct. Like these authors, I hadn't read it recently either. I quote a few selected paragraphs from that code:

> "In all of his relations the engineer should be guided by the highest principles of honor.
>
> "The engineer should endeavor to assist the public to a fair and correct general understanding of engineering matters, to extend the general knowledge of engineering, and to discourage the appearance of untrue, unfair, or exaggerated statements on engineering subjects in the press or elsewhere, especially if these statements may lead to, or are made for the purpose of, inducing the public to participate in unworthy enterprises.
>
> "It is unprofessional to give an opinion on a subject without being fully informed as to all the facts relating thereto and as to the purposes for which the information is asked. The opinion should contain a full statement of the conditions under which it applies.
>
> "An engineer in responsible charge of work should not permit nontechnical persons to overrule his engineering judgments on purely engineering grounds."

I submit that such a code has something vital to do with Democracy. If we believe in it, if we have any pride in and respect for our profession and ourselves, let's not just talk about these principles, let's have the courage to live up to them.

YOU AND THE PROFESSION

WHAT I have to say under this heading I want to say to all members of the Institute. I shall cover that in my prescribed Presidential address at the annual meeting in Pasadena, Calif., during the 1950 Summer and Pacific General Meeting. I hope I have aroused your curiosity sufficiently so that you will read these pages next month.



Power Station Centralized Control

Centralized Control for Steam Power Stations

B. C. MALLORY

Recent trends in steam power station design include centralization of instruments and controls. These articles describe stations that have incorporated centralization in their design, tell of the advantages and disadvantages discovered with this type of operation, and compare savings in labor costs with added investment in instruments.

THE ULTIMATE in centralization of instrumentation and controls for a steam electric power station might be considered as only one operator for the whole station; this operator would be sitting in a quiet air-conditioned office with one load indicator and one control to start, adjust the load, and stop each main turbine generator. The boiler for each unit and all other equipment would operate automatically, and the man's only duties would be to operate the load controls in accordance with telephone dinstructions from the system load dispatcher. However, this ultimate in simplification is neither economical nor feasible for present-day steam turbine generators, boilers, and auxiliary equipment.

Once started and put on the line, a turbine with its boiler and complete set of auxiliaries may be so equipped that it can be operated automatically, but present-day equipment and controls are not sufficiently trouble-free, even with the best of maintenance, and they are not trusted to operate satisfactorily without adequate attention. Nor have automatic controls been devised to start either a turbine or high-pressure boiler without manual assistance and careful checking by operators.

There is a vast amount of thought and effort that should be applied to developing reliable controls for automatic starting of boilers and turbines, especially from an overnight stand-by condition. Managements are asking engineers to consider some automatic time-clock device, possibly with temperature- and vibration-sensitive adjustments to co-ordinate starting procedures properly, both from the viewpoint of uniformity of operations and ease of control.

Separate control points for each turbine generator and

Essential substance of paper **50-91**, "Centralized Instrumentation and Controls for Steam Electric Power Stations," recommended by the AIEE Committee on Power Generation and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N.Y., January 30-February 3, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

B. C. Mallory is chief mechanical engineer with Stone and Webster Engineering Corporation, Boston, Mass.

each boiler have been common practice in the past, with a separate switchboard room. Now, with increasing costs of operating personnel, more emphasis is being given to aggregating main control points at centralized locations in order to require the use of the fewest possible men. For medium or large modern boilers or turbines, each control point may require an instrument and control board as much as 30 feet long, and each panel becomes complex with hundreds of indicators, recorders, controls, and alarm lights. To assemble several of these boards at a central location requires considerable space.

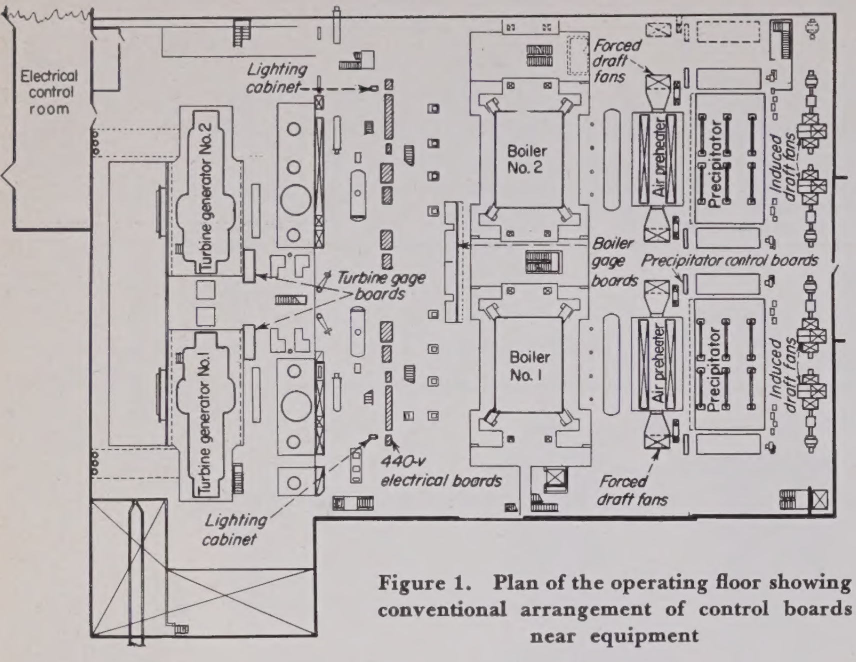


Figure 1. Plan of the operating floor showing conventional arrangement of control boards near equipment

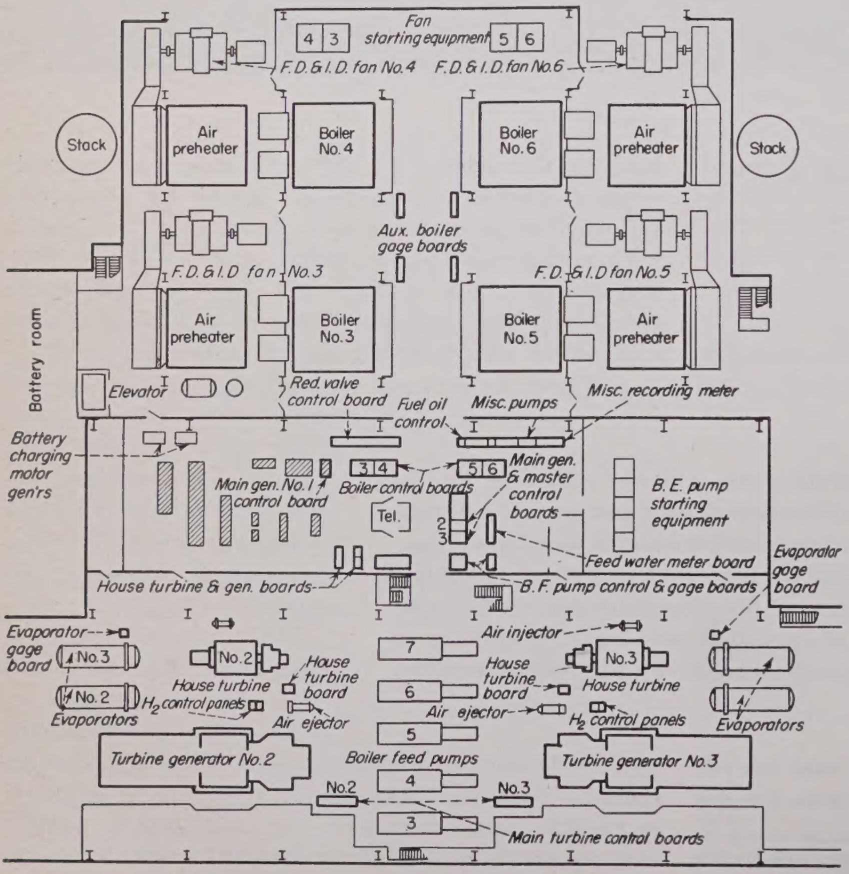


Figure 2. Centralized-control arrangement in this plant reduces operating crew to seven men per shift. Control room operators handle both the mechanical and electric boards

There is a wide divergence of opinion among designing and operating engineers with regard to the amount of centralization of control that is practicable. The problem of the extent of advantageous centralization revolves about the number of manual controls that can be handled by one man in time of trouble.

One man can supervise many controls while everything is functioning properly and units are neither being put on nor taken off the line, but in times of trouble the number and complexity of the controls that one man can handle depend to a large extent on the panel layout and the ability of the man. The number can be increased safely to some extent by a logical arrangement and use of different types of control handles for different types of control so that routine adjustments become simplified and, in emergencies, the operator acts from habit without having to think out each step of what he should do.

Too often the artistic appearance or the space needed in the back of the panels for instruments has governed the board layouts. There is a need for miniature mechanical instruments comparable to those on electrical boards or to those used for large airplanes. For ease and reliability of operation, the instruments and controls should be segregated to permit manipulating the vital controls from a central point. Instruments needing minor manual adjustments and recording instruments should be located at some less strategic point.

The advantages of complete centralized control with the switchboard located in the control room are

1. Reduction in number of operators minimizes cost of operating personnel.
2. Presentation of all pertinent data to one operator gives a better understanding of the plant as an integrated co-ordinated unit.
3. Operator can take corrective action simultaneously for two or more operations, should conditions so demand.
4. Communication errors are avoided.
5. Quality of operation is improved. The

better operating conditions of the centralized control room attract a higher type of personnel. This means more than better thermal efficiency as it should give better maintenance of load during upset conditions, quicker restoration after an interruption, and better judgment in preventing an interruption.

6. More automatic controls may be required, which tends to free the operator from details and permit more supervision.

The disadvantages of complete centralized control with the switchboard located in the control room include the following items:

1. Space required for control room in heart of station adds to initial construction cost by adding building space and may add it for the full height of the station.
2. Each additional instrument and control adds equipment to be maintained, and each is a potential source of trouble because it may function incorrectly.
3. Complexity of many instruments, controls, alarms, and lights requires a considerable training period for operators, especially if the mechanical and electrical men have to substitute for one another. With two mechanical men and one electrical man in a control room, this substitution might easily be required.
4. Cost is increased due to either duplication of controls or longer runs of instrumentation and control leads and the space required for them.
5. Pay rates must be higher for operators having greater responsibility.

Figure 1 shows the main operating floor plan of a decentralized station which has two 850-pound-per-square-inch-gauge 900-degree-Fahrenheit 80,000-kw units and two coal-fired boilers. The two boiler panels have been combined so that the men operating the boilers have a common control point. The two turbine generators have been located with their steam ends together so that the turbine operators have control points close together. The electric control room is separate, just outside the turbine room, and approximately centered on the expected ultimate station of four or five units. This arrangement was preferred because the owner objected to combining the boiler and turbine boards on the basis that boiler and turbine operators are not readily interchangeable.

Figure 2 shows the operating floor plan of a plant extension having two 1,300-pound-per-square-inch-gauge 950-degree-Fahrenheit 100,000-kw turbine generators and four oil- and gas-fired boilers. This extension has a complete centralized mechanical and electric control room located at the crossroads between the boiler and turbine rooms. In addition, there are individual gauge boards at the various equipment items for the use of the operators of the different equipment.

The control room is 40 feet by 130 feet and has 378 annunciator drops. This utility soundproofs only the telephone booth and prefers to have the operators noise conscious with respect to the plant.

Many of the advantages of a centralized control room may be gained, and some of the disadvantages eliminated, by having a centralized point for the contol of each single boiler-turbine located between the two. The switchboard should be in a separate room where the electric controls for several such single boiler-turbine units and those of the outgoing lines would be located.

Design and Operation of Central Control Rooms

B. F. BORGEL

THE CENTRAL control room of the Warren, Pa., station of the Pennsylvania Electric Company is a balanced combination of control and supervisory rooms, and is a result of that company's investigation into the field of centralized control. This particular installation is serving as a proving ground for various changes which will be incorporated in future plant design and will be used to illustrate the engineering policy being followed by the Pennsylvania Electric Company.

Because of the peculiar operating problems encountered on this system, the need for faster communication between the various operators on duty in a station has long been recognized. This system, which is spread over a mountainous area 300 miles in extent, is subjected to severe disturbances from electric storms, which frequently isolate a generating station from the system, causing the loss of all load except that in the immediate area. During these conditions, the plant facilities must be maintained in such a manner which will permit immediate load pickup when tie lines are reclosed. In order to take advantage of the low generating costs of mine-mouth plants, power is frequently transmitted as much as 200 miles into the metropolitan areas. During these periods, the area plant must be able to pick up load from minimum to maximum in the event of any tie-line disturbance and to accomplish this without any objectionable drop in voltage or frequency.

The first attempt to effect faster internal plant communication was the installation of telephone stations at key operating positions. This led to the use of common loud-speaker systems, arranged to provide coverage of all operating locations. Location on boiler control boards of the governor control of the turbine served by that boiler occurred next, thus turning over to the boiler operator the control of turbine load. These moves speeded operation during emergencies, and gave more efficient operation during normal periods, but underlined the necessity for one key operator.

Operation of the plant was facilitated by grouping of associated equipment and locating the various groups in a functional sequence. Vertical segregation of all equipment was followed. On the station power boards, the switch controls are arranged horizontally by voltages and vertically by sequence of operation, as pictured in Figure 3. Maximum usage has been made of all available types of handles for control stations. Thus pistol grip denotes circuit-breaker control, oval is used on remote operating controls, round smooth on governor and field controls, round knurled on current and potential transfer switches. The instruments and draft gauges which indicate the changes resulting from control operation are located vertically above the

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Essential substance of paper 50-92, "Design and Operation of Central Control Rooms," recommended by the AIEE Committee on Power Generation and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N.Y., January 30–February 3, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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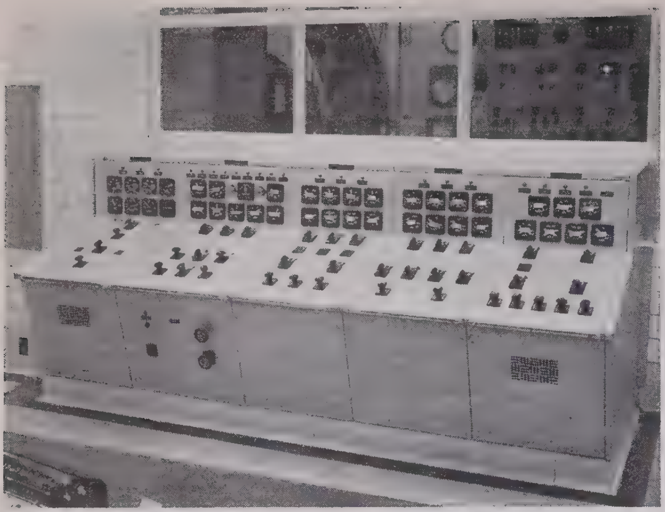

Figure 3. Control room board showing different types of handles in use. Switch controls are arranged horizontally by voltages and vertically by sequence of operation

corresponding control stations on the panel boards. The primary objective throughout was to provide a layout that would help the operator to think and to follow the correct sequence of operation.

The Warren plant was placed in service on August 15, 1948, and operation since that time has justified the faith of the engineers in the advantages of a central control room. The plant was manned with experienced operators in the central control room and new operators with no previous power plant experience in all other operating posts.

No misoperation by the new operators, who work directly under orders of the control operator, has resulted to date. During start-up a total of 17 trip-outs of the machines at full load occurred due to staged relay testing and accidental trip-outs. In all cases, the machine was resynchronized and the plant returned to full load in less than five minutes.

This operating condition was duplicated in another plant of this system which is identical in design with Warren, lacking only the central control room, and a minimum of 11 minutes was required from trip-out of the generator to re-establishment of full load on the unit.

Experience indicates the following changes be incorporated in future installations:

1. Concentrate on the board fronts only those indicating instruments which are required for minute-to-minute operation.

2. Relocate the generator hydrogen panel next to the hydrogen equipment to guide the operator in making adjustments to the hydrogen supply to the generator and to eliminate the hazard of hydrogen leakage into the control room.

3. Use pressure-transmitting devices with the sender located at the pressure points and multiple indicating units in the control room and at other required locations, to avoid the danger of a pressure blowout in the control room.

4. Apply phase-angle control of tie-line loading and frequency to combustion control as well as to the governor control of the turbine.

5. Arrange the control room so the control room operator can see the plant equipment. Experience has indicated that it is inducive to better operation if the operator is able to see the equipment he is operating.

6. Restudy the lighting problems in the control rooms. Reference to Figure 3 will show that the high light intensity in the control room causes the Thermopane glass enclosing the room to act as a mirror and hampers outside vision.

The Warren plant, consisting of two 30,000-kw-rated generators operated on a continuous basis at 40,000 kw each, is operated with six operators per shift, and a total force, including supervisors, of 53 men. Accurate cost data of the control room versus conventional design have been compiled and show the additional cost of the Warren design to be $60,000 or $1 per kilowatt of nameplate capacity. The direct savings accruing from this expenditure is the elimination of two shift operators, evaluated at $35,000 per year total. No attempt has been made to date to evaluate the return represented by faster and more efficient operation of the plant when required, but it has been a sizable amount.

Centralized Control in the Middle West

J. M. DRABELLE
MEMBER AIEE

JUDGED by metropolitan standards, the generating stations of the North Central section of the United States are quite small. A large steam turbine is the 40,000-kw size and the prevailing sizes are from 7,500 kw to 20,000 kw.

The changing pattern of transmission and subtransmission voltages, which in the North Central United States are 34.5 kv, 69 kv, and either 115 kv or 161 kv, lend themselves to the rural station, and this dictates part of the electrical design, as local service is usually not supplied from such generating stations. The improvement in the reliability of all classes of power station apparatus, mechanical and electric, in the past 25 years has caused a definite trend toward the unit type of station.

The unit-design station has the definite advantage of: the elimination of the costly maze of interconnecting piping and valves; the costly intermediate electric gear, together with its attendant rupturing-capacity problem; a simplification of the boiler feed-water problem as trouble with feed water in one unit is confined to that unit; centralization of control. All of this spells lower investment and labor costs.

Centralized control places all of the essential operations of the steam generating equipment, steam utilizing equipment, and transmission lines in one convenient place under the eye of one operator, which spells economy in labor. At some convenient central point is the control station for the coal-conveying and coal-handling equipment, and these control points are usually interlocked to prevent false operation of conveying, crushing, and unloading systems.

Several such stations are now in operation in Iowa.

Figure 4 shows part of the centralized control station of the 10,000-kw high-pressure generating unit of the Iowa Electric Light and Power Company at Boone, Iowa. The gray panels are, from left to right, exciter and synchronizing panel; next, panel for the incoming 115-kv line and one 34-kv outgoing line; the next panel, three outgoing 34.5-kv

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J. M. Drabelle is chief engineer with the Iowa Electric Light and Power Company, Cedar Rapids, Iowa.

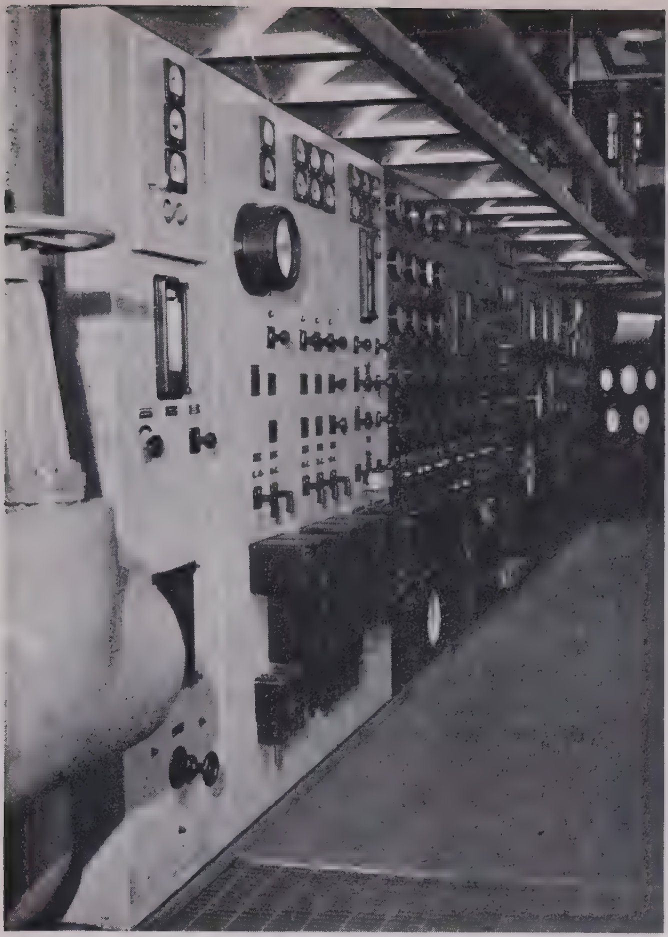

Figure 4. Part of the centralized control station of the Iowa Electric Light and Power Company plant at Boone, Iowa

circuits, and the right gray panel, the electric control panel for the turbogenerator.

The Beaver Channel station of Interstate Power Company is an example of a semioutdoor station in a cold climate where temperatures at times reach −30 degrees Fahrenheit. All of the high-voltage electric gear, with the exception of the control panels and the auxiliary power supply control panels, is installed outdoors.

The Interstate Power Company has constructed two new generating stations in Iowa (two 15,000-kw generators), one at Beaver Channel (one 15,000-kw generator) near Clinton, and another at Lansing, Iowa. A third station is now under construction at Sherburn, Minn., on the shore of Fox Lake. Figure 5 shows line panels and turbine electrical output panel at the left, together with hydrogen control and the turbine mechanical panels, pressure gauges, mercury columns, showing the various pressures in the cycle and control switch stations for the control of auxiliaries.

There are three outstanding items determining the cost of a station. These are invested capital, labor, and taxes. The operating force required for the various stations discussed consisted of 19 to 21 men, including the chief engineer and his assistant to the coal-unloading and ash crews. Labor is a never-ending operating charge. When compared to other stations of conventional arrangement, these stations used 25 to 50 per cent fewer operating employees, an annual saving that cannot be overlooked.

Single Boiler-Turbine-Generator Units

J. A. LIND J. M. GEIGER
MEMBER AIEE

WHEN Oswego Steam Station of the Niagara Mohawk Power Corporation was being designed in the late 1930's, a unit system was decided upon, a unit consisting of a boiler, turbine, and generator. No steam, feed water, or electric interconnections at greater voltage were provided between units. The merits of the unit system in this case have been described elsewhere.[1] The controls for such a station required an entirely new approach and presented an opportunity for major improvement.

In such a station, with two or more units with no mechanical or electric interconnections except the transmission system, when the station load is to be changed either unit may assume the whole change or both may share it. If the total station output is to remain constant but reapportioned between units, both boilers are subjected to the conditions which accompany a station load change. As the load on one unit is changed, all of the pump outputs must be changed, and the firing rate of that unit's boiler must be changed, requiring change in output of pulverizers, feeders, and feedwater regulators. It is valuable that the several operators know the magnitude and speed of load change on the unit they are handling as quickly as possible. There are three ways of speeding up this intelligence:

1. Install duplicate instrumentation at the several locations.
2. Use a public address system.
3. Locate all affected operations at one point.

Studies of loadings for the Oswego Steam Station indicated that it would be largely a bulk power producer, and there would be periods of minimum load, stand-by service during heavy run-off to the system's hydro stations, and periods during which it would be regulating. It would be tied into the 115-kv transmission system, and there would be few local feeders. These conditions required that each unit be capable of operating over a wide load range and that flexibility of control be provided to meet the variable demands of the system.

A "straight-line" organization was conceived for each unit, with a "unit operator" who would be in a position to supervise all operations of one boiler-turbine-generator unit. Normally he would control input to suit output, but he would also control output so as not to exceed the capability of the unit. In working out details of such a system, including arrangement, cost, and personnel, it appeared more feasible to apply the scheme on a 2-unit basis.

A central control room was located in the building bay between units, and in it were installed switchboard for the two generators, their exciters, and related auxiliaries, together with a mechanical control board for each of the boiler-turbine units and their auxiliaries. The electric board contained the usual switchboard controls and meters,

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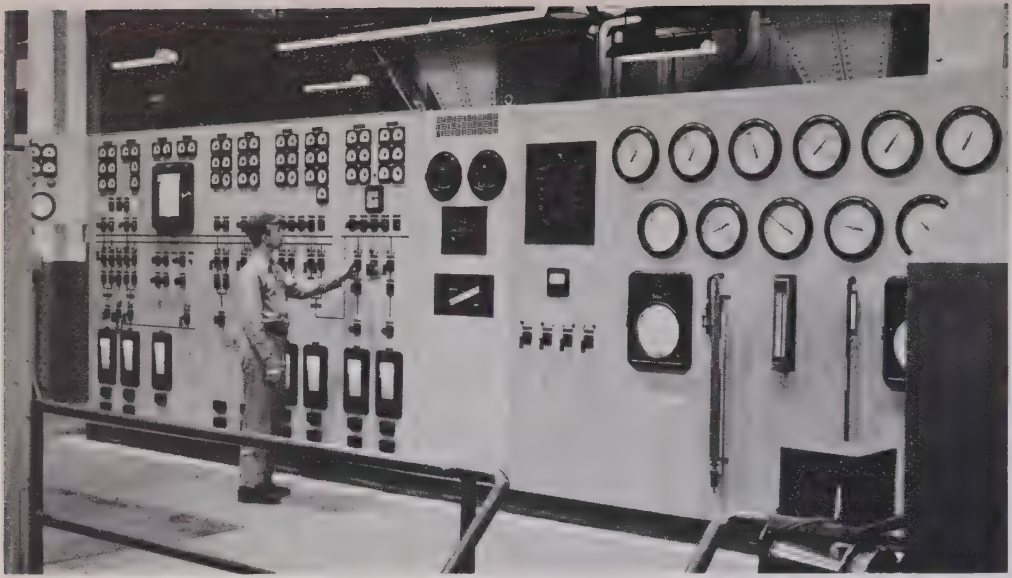

Figure 5. Line panels and turbine electric output panel are shown at the left. The hydrogen control and turbine mechanical panels, pressure gauges, mercury columns, and control switch stations for the control of the auxiliaries are also shown

and the mechanical control board contained those instruments, meters, gauges, and controls usually found on the boiler control panel and turbine control panel. The main control panels were kept small by bringing only essential controls and instruments to this location. To illustrate, at each boiler feed pump there is a local panel with flow meter, pressure gauges, push buttons for auxiliary oil pump, recirculation control relays, and thermometers; in the control room there are only an ammeter, control switch, air control subpanel, and a telemetered flow indicator in a multiple-draft-gauge type of instrument.

Operators communicate with auxiliary operators either by telephone or public address system. Abnormal operating conditions are called to their attention by an annunciator. Principal auxiliaries of the main units are under their control. This equipment is generally stopped and started manually, but automatic speed and throttling control is provided. So far as possible, related instruments and controls have been grouped together.

The mechanical panel has a section for soot blowers, then a section for pulverizer and burner controls. This is followed by the steam-pressure and combustion control, including control switches for draft fans. Controls for the turbine and its auxiliaries are at the turbine-room end of the panel. Control of condensate from the condenser to the boiler is located on a section of the panel between the boiler controls and the turbine controls.

The central section of the electric switchboard contains frequency and tie-line loading controls. On either side of center there is a section for instruments and controls associated with one unit, followed by panel sections for auxiliary power boards. Towards the ends are panel sections for local feeders. Station watt-hour meters are on the end wings of the panel.

It seemed unimportant that the unit operators have control of functions related to start-up; hence remote control of these items was provided only when convenient. While steam-jet air ejectors may be added or removed from service during operation, the need for them is not a function of load on the machine. The evaporator plant was not placed in the centralized group because the immediate demands of the unit are supplied from condensate storage tanks, and the evaporators need not be co-ordinated with operation of the main units. Control of automatic soot blowers might also have been omitted from centralization, but it was convenient to include them.[2]

Some operators will advocate separation of electric controls from the boiler and turbine controls. The authors have no disagreement with such separation in some instances. It is conceivable that some plants, located in load centers, may require more space and personnel in connection with transmission and distribution than in connection with the electrical control of the generating units. In such instances, it is suggested that consideration be given to separating the extraneous jobs from the power plant jobs instead of separating the power plant jobs. If sufficient extraneous electric controls are to be located in the power plant, a separate control location might well be established for them.

The value of closely co-ordinated operation of a unit by means of centralized control is illustrated in nearly every operating abnormality.

For example, when there is an alarm of coal failure to a mill, the electrical operator is alerted immediately and stands by to keep steam pressure up. This results in load drops of five or ten megawatts for a few minutes on two or three days a month during wet and frozen coal periods. Probably the load drops would be greater due to efficiency loss if steam pressure were allowed to fall off.

When operating on block loads and the load supervisor calls for a change, the switchboard operator announces what is to be done as he steps to the panel. The mechanical man will advise him if there is reason to make the change in any manner different from normal. If a quick change is required, the rate of change is determined by ability to maintain water level, steam pressure, draft, or whatever is most critical at the moment. If electrical trouble occurs, the boiler operator likewise knows at once the nature of changes necessary to restore order.

The desirability of centralized controls in generating stations of the independent unit type of design has been confirmed by nearly ten years of experience with two units at Oswego. Observations at Oswego and independent studies have demonstrated its advantages to a different operating group which is experienced with separate electric control rooms.

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Central Control at Sewaren Generating Station

F. P. FAIRCHILD

WHEN the present work on the Sewaren Generating Station of the Public Service and Gas Company in New Jersey is finished in 1951, the plant will be a 455,000-kw station embodying unit design with central control of the four units in pairs. The first two units started operating in December 1948. Throttle steam conditions are 1,500 pounds per square inch gauge and 1,050 degrees Fahrenheit. The station is arranged to burn coal, fuel oil, or natural gas. All auxiliaries are motor-driven.

Figure 6 shows the principal elements of the first pair of units in plan. The control room is near the center of the area occupied by the equipment it controls. It is situated on the upper of the two principal operating floors of the station. It encloses the essential instruments and controls for its pair of units with the exception of the fuel- and ash-handling systems, the air compressors, the traveling screens at the circulating water intake, and station service equipment such as elevators, ventilating systems, and the like.

A view of the electric controls and instruments for the first pair of units is shown in the title block. The controls are on the benchboard. The meters are on the panel above the windows. The visual alarm indicators are above the meters. Recorders are mounted on panels around the corners, facing the windows. Alarm stops with their indicating lights are located on the front of the benchboard. The two turbine generators can be seen through the windows, which are double-glass and nonreflecting. The room is soundproofed and air-conditioned.

Figure 7 shows the mechanical controls and instruments

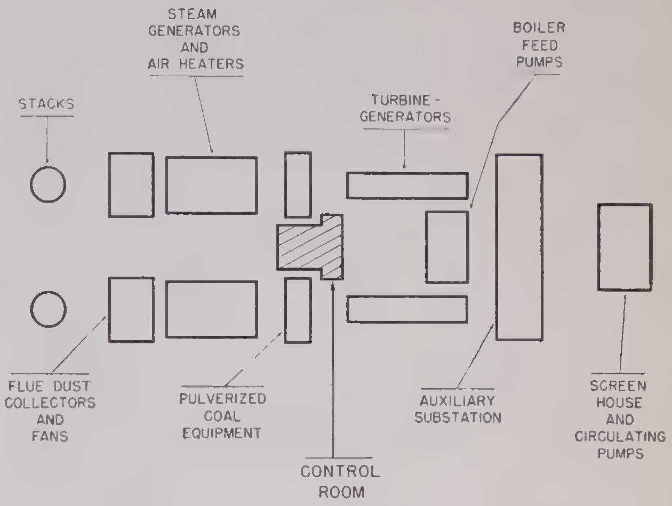
STEAM GENERATORS AND AIR HEATERS
BOILER FEED PUMPS
STACKS
TURBINE-GENERATORS
FLUE DUST COLLECTORS AND FANS
PULVERIZED COAL EQUIPMENT
AUXILIARY SUBSTATION
SCREEN HOUSE AND CIRCULATING PUMPS
CONTROL ROOM

Figure 6. Plan of the principal equipment of the Number 1 and 2 units at the Sewaren Generating Station, Sewaren, N. J. The transformer yard is to the left of the stacks

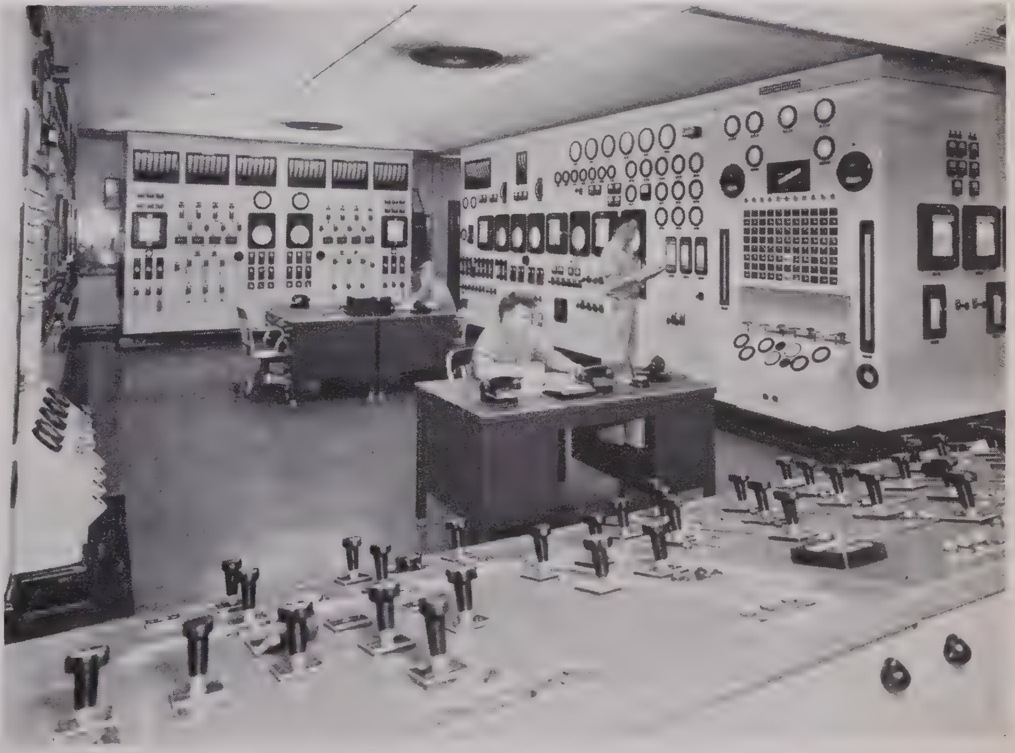

Figure 7. Mechanical controls and instruments for one pair of units. The nearest burner observation ports of the boiler can be seen through the rear windows. The operator faces the panels of his unit. The coal pulverizer control is on the end panels; boiler control is at the left of the long panel; turbine control is on the right

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for one of the pair of units. In general, the relative arrangement of the panels is consistent with the relative arrangement of equipment in the plant. The operator sits at his desk, facing the panels of his unit. Coal-pulverizer control is on the end panels. Boiler control is at the left of the long panel; turbine control is on the right. The "soda fountain" at the right controls the turbine-gland seals. Mechanical alarms are just above the "soda fountain." The operator can see the nearest burner observation ports of the boiler through the rear windows and thus assure himself that there is fire in the furnace. For each unit there is a multipoint recorder which monitors main-unit and auxiliary bearing temperatures and sounds an alarm for excessive temperature.

The panel designs are based on consideration of visibility, accessibility for operation and maintenance, and simplicity. Although the size of some of the instruments is smaller than that found in other plants of the system, the spacing is sufficient to permit maintenance work on an individual item without disturbing the adjacent items. In general, direct-reading instruments are used on the mechanical panels. Telemetering is used for the natural gas pressure gauges to avoid the hazard involved.

There are three operators on duty in this control room. One is responsible for the electric equipment of the pair of units. Each of the other two is responsible for the mechanical equipment of one unit. As each of the three men is trained to operate any one of the three jobs, he stands ready to assist the others in time of trouble or temporary absence. They rotate around the jobs in the control room regularly, staying in each position about a week at a time. The men have performed very well both as electrical and mechanical operators, and there has been no noticeable difference in proficiency in respect to background, mechanical or electrical. The experience of such an operator is excellent training for load dispatcher.

One advantage of having two control rooms, one for each set of two generators, lies in the isolation of each room during emergencies. If one has trouble, the other continues operation undisturbed by the difficulties of the first. Communication between the two control rooms is available, if necessary, over the public address system.

The operators like central control because each one is in a position to have instantaneous communication with the others, and that makes for a smoothly working team. When it is necessary to drop load, under emergency or normal conditions, the electrical operator brings it down in harmony with the mechanical operator, thus avoiding popping safety valves, dips in steam pressure, and other undesirable operating conditions.

An Engineer Looks at Mathematics Teaching

EVERETT S. LEE
FELLOW AIEE

In this article, originally presented as an address before the National Council of Teachers of Mathematics, Past President Lee discusses the importance of mathematics courses in our educational programs—for, as he points out, mathematical concepts are essential not only to the work of the scientist and the engineer, but, in fact, to the work of the world.

THROUGHOUT my engineering life I have been privileged to have been associated with one of the large laboratories of the General Electric Company, the General Engineering and Consulting Laboratory. This is a measurements and engineering development laboratory, serving the entire engineering staff of the company, together with associated manufacturing. It takes new knowledge from the scientists of the Research Laboratory and fashions it into metal and material, and serves today with a heritage from the past of those master minds, Dr. Steinmetz, Dr. Alexanderson, and Dr. Lewis Robinson. Because of our associations with the other laboratories of the great industries and schools and government of our land and with their engineers and scientists, I trust that in presenting our experiences I can also be speaking for them, although this is by association only and not as their direct representative. To many people the inhabitants of a laboratory are eccentric, different from everybody else and limited in their concepts of life. This is not so. Having established this fact, I want to add quickly that the techniques in the engineering laboratory as regards mathematics extend out into the engineering field and into the life of engineers broadly, both in the technical and general aspects of their living. So it also is with scientists. Within and beyond the laboratory there is little fundamental difference regarding mathematics.

We all need mathematics. Everybody has to know how to add, though few can add a column of figures accurately

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Essentially full text of an address, "An Engineer Looks at Mathematics Teaching," presented at the annual banquet held during the 28th annual meeting of the National Council of Teachers of Mathematics, Chicago, Ill., April 12–15, 1950.

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and quickly. Teaching of mathematics should be undergirded in this regard; addition should be made a continuing part of the curriculum as should subtraction, multiplication, and division.

For the scientists and the engineers algebra and geometry are also essential, principally for two of the mathematical concepts: the equation, and the plotting upon squared paper of the equation. Here are fundamental concepts of the greatest import. They co-ordinate immediately with what I feel is the greatest attribute of mathematics, that it is the means whereby phenomena are visualized for practical use.

If there is any thought in the mind of the student who does not understand mathematics and its place in his life, and the reason for him having to master it, it is that, first, he does not understand where he will use it and, second, that it is too difficult. I am confident that if he can see where it will be useful to him, he will give of his abilities to its mastery.

IMPORTANCE OF MATHEMATICS

The mathematician may put mathematics first but I put it second. To me the phenomena is first and mathematics second, but we need them both. Both are essential, so whether first or second is important only as a factor in establishing the proper concept.

Ma does not go to the grocery store to add up a column of figures; she goes because Pa and the kids and she must eat. Hunger is the phenomenon; the mathematics in the grocery store comes as a direct consequence of that phenomenon.

So it is in our engineering and scientific lives. The phenomena which the schools of science teach in the natural sciences are fundamental. When the phenomena are understood, completely or even partially, there is the urge to apply them. Here the mathematical equation comes into play, for the expression of the scientific phenomenon in one line is the equation of mathematics. This requires both scientific and mathematical knowledge; the scientific to visualize the phenomena and the mathematical to put the visualization into equation form. Further mathematical knowledge is then needed in the solution of the equation to result in an expression of variables. Substituting real values for the variables allows the phenomena to be resolved into practical use.

This is the picture which the science teacher, together with the mathematics teacher, can bring to the young student better than can anyone else in any other way. In high school the presentation will have to be confined to arithmetic and algebra and geometry, for these the student has had. The application here will please him since he is using mathematics he has learned previously and since he is finding in science a use which he could not advance in any other way. Thus his scientific knowledge and his mathematics knowledge will go forward together to bring him ability in visualizing phenomena and in using his mathematics to make those phenomena useful.

Those who hold the opportunity for bringing this concept to the young scientist and to the young engineer, and who will help him to nurture it, will be putting into his scientific and engineering life one of his most valuable acquisitions. It is what made a Steinmetz; it is what has made many a famous engineer and scientist. It is what the mathematics teacher can provide for a life of greater usefulness for his students.

As these inspiring opportunities of mathematics are brought to the students, some of them will be keenly interested in going on and on to find further applications of the precepts they are learning. Among these are the engineers of tomorrow. We are especially interested in them as they continue to learn and to show an ever-increasing interest in the new and a growing desire to use it. These are the boys—and the girls, too—who will be entering engineering schools to learn more that is new, and to build on that of which they have knowledge. In the days to come they will be entering their engineering careers to continue to bring to mankind even greater services than he has yet had provided for him.

Some of the youngsters in these mathematics classes will be especially keen in scientific perception and observation. They will move ahead into unknown fields faster than their fellows. From these will come the scientists of tomorrow, who will continue throughout their lives to bring new knowledge into being—new knowledge of our universe and of all that is therein—that this new knowledge may be made available for the engineer to fashion into material for the use of mankind.

The teacher has in their formative years the boys and girls from whom will come the scientists and the engineers of tomorrow. What greater wealth could there be? He shapes and guides them in their beginning years. His is a responsibility of the greatest of service; his is a responsibility to all mankind.

THE LONG PROCESSION

Every material thing we have comes from the scientist and the engineer. The paper upon which this article is printed, the press which printed it, the train which transported it, all came from the scientist and the engineer. The men of science and engineering gave us the houses in which we live, the furnishings, the lights, the street outside, the buildings of the city, the telephones, the telegraph, the movies, radio, television. The farm equipment on the farms, the roads, the automobile, the airplane, the electric power for home and industry were created by the scientist and the engineer. The tanks, guns, airplanes, ships, and ammunition of war production all came from the scientist and the engineer. The opportunities for all of the people to work in peace have come from the scientist and the engineer, as will the opportunities for all people to work in peace in the future. It is the teachers who have these scientists and engineers in their youth; theirs is the greatest of responsibilities.

The line from the research laboratory and the model shop of the engineer to the fact of the product in the hands of the people is a long one. In it stand the great industrial leaders who have led us to bring forth large companies, and medium-sized companies, and the many, many small companies which are our great industrial strength in this country to progress the products of the engineer. In it stand the workers in the shops who, with the proficiency of their hand

and eye, operate the machines to turn out the products of the engineers for the people to have and to use. In it stand the salesmen who separate the dollars from the people for the products, and the products thus finally get to the people for their use and enjoyment. This is a long and noble procession.

There is also another group of people entwined in this procession. There are the doctors who keep us in good health. There are the lawyers who keep us in line and keep us out of jail. There are bankers who provide the wherewithal to give us a start and to help in keeping us going. There are the ministers who guide us in paths of righteousness. There are the boys in the Service who are keeping us at peace. Last, but by no means least, are the school teachers who impart knowledge and wisdom and understanding all along the line to all those entering the procession that it may be continuous and of ever-increasing ability. They undergird the entire procession. They maintain it. They are responsible for its advance. They have a responsibility which is as great as they can fulfill. They leaven the process. Without the school teachers the entire process stops.

Mathematics has a vital place in this picture. Without it everything would stop. There would be no trade. There would be no production. There would be no measurement. There would be no statement of result. There would be no communication of ideas. There would be no evaluation of project. There would be no co-ordination. There would be no fact.

I do not presume to expound on how to teach mathematics, but I do want to emphasize that when the mathematics teacher can get his young students to see and visualize phenomena in nature and can bring to his students the importance of mathematics in this picture, then he is laying the foundation for scientific and engineering advance. He must lead them to try to understand these phenomena, to cogitate upon them, to build with them upon that which they already know. Let their imagination run wild with the opportunities for the use of the phenomena. This is what has brought us to where we are today and will carry us to better things to come.

I realize, of course, that most young people in mathematics will not become either scientists or engineers; but they will become doctors or bankers or lawyers or politicians. They will become merchants or tradespeople or artisans or farmers or clerks or housewives to take their place in the great procession of what we are all doing together. All of these need and can use the same training; it is fundamental to the existence of our people. In fact, it is even more important that those who use the products of the scientists and the engineers use them for good and not for evil. This is the desire of the scientist and of the engineer; equally important, this should be the motive of those who use their products.

I know of no surer way to bring the teachings of right and wrong to young people than by disclosing the laws of natural science and of mathematics, their exactness and their constance of behavior, as contrasted with the behavior of man. I know of no group better equipped to do this than those who teach science and mathematics to the youth of the land. I speak from personal experience in my own case, and I have been privileged to have been associated with many engineers and scientists who, I find, understand these fundamentals. For this I have naturally given credit to those, the teachers, who play the beginning role in their scientific lives.

If what I have said is not new, I say again for emphasis that it is still the truth. If it is new to some, I say it with a conviction that it is essential to our continued advance, that it be for great good.

Together with all these, I trust that the mathematics teacher may, as there is opportunity for him to do so, bring to his boys and girls the knowledge and the conviction that there must be a power behind all nature greater than the power of man, a mind greater than the mind of man, and a life greater than the life of man. Unless it were so, these things could not be. As he brings to the boys and girls the knowledge that the laws of nature and of mathematics cannot be broken, so there should be the knowledge also that the laws governing human conduct cannot be broken without redress.

MATHEMATICS APPLIED

I BEGAN with algebra and from it I have brought in all of the fundamentals I know as they exist in this picture. Trigonometry is next, followed by college with analytical geometry, descriptive geometry, the calculus, integral and differential, and differential equations. Most students stop here, but some, as they have the ability, continue on. It is good that those who can, do travel far along the mathematical boulevard, always keeping in mind the scientific phenomena which they can better clarify and unlock for the use of man as they progress.

In this regard, the following are a few applications of mathematics beyond the usual. Note the practicability of the problems to which they are applied.

Bessel's functions are applied to the problem of the cooling of a gas-turbine wheel. This new power development of the past few years has been made possible by the availability of higher temperature materials to give efficiencies in prime movers beyond any previously attained. Bessel's functions also arise in expressing a frequency-modulated signal as an infinite series to analyze the fidelity of sound transmission of this communication method, and they occur also in the study of cylindrical wave guides and in calculations of drag on finite supersonic air foils.

Tensor analysis is another new field beyond the usual. Gabriel Kron has done a great deal of work on the equivalent circuits of electric machines, that their design may be more efficient, their performance better, their cost less. Tensor analysis also has been applied to the solution of steel-mill control problems. One unusual problem for solution by tensor analysis was that of the mechanical linkage in a gun-fire computer subjected to a sudden acceleration caused by gun recoil.

Conformal transformations have their place in the most practical of problems. In the problems of the fringing flux in a d-c machine, using a Schwartz-Christoffel transformation, it was possible to calculate the amount of flux between the main pole and the interpole. The problem of the amount of heat conducted through a corner of a thick rectangular duct may be solved also by using a Schwartz-Christoffel transformation, and the problem of lift on air foils may often be solved by using a transformation to transform the air foil to a simpler shape.

A simple problem in solving Legendre polynomials is to determine the field pattern of an antenna made of two hemispherical shells closely spaced. One application of elliptic integrals is in the calculation of a high-frequency inductance and radiation resistance of a coil; another application is the calculation of viscous flow in liquids for non-turbulent motion.

The theory of characteristics is used in the solution of problems in gas dynamics involving 2-dimensional and axially symmetric supersonic flow.

Considerable application is made of the methods of operational calculus using both the LaPlace transformation and Heaviside's operators. They are used in problems involving servomechanisms, transmission-line systems, transient and steady-state performance of electric machinery, and electric and mechanical networks. To understand these operational methods, the engineers using them have become familiar with complex variable theory.

These concepts, among the advanced of the mathematics, are applicable to many problems, problems which need the best of scientific and engineering knowledge and ability for solution. Most people little realize how much knowledge is put into engineering designs. The mathematics teachers hold the key to that phase of mathematics which produces results that can be achieved in no other way except occasionally by hunch or by unusual perception. These are the exception, however, not the rule. And, of course, there are some who will advance mathematics just for the sake of mathematics. These persons we need also for their great power.

In between the early fundamental concepts of the student in the early school and the applications of the most advanced mathematics reserved for the relatively few, an enormous amount of mathematics is used by the thousands of engineers and scientists in their daily engineering lives. This also the mathematics teacher supplies, and the greater its understanding and its application, the greater is his contribution and the more effectively is he progressing his responsibility. So effective has it been that I hesitate to advance anything new or even to try to suggest any detailed opportunities for improvement, although, of course, there are many opportunities for improvement—for there is always a better way.

I do want to emphasize one phase of fundamental importance—that when appreciation and understanding of the phenomena involved are brought together with the mathematical knowledge, then the two are progressed together to a result attainable in no other way with comparable exactness and certainty of attainment.

I was privileged to have as one of my teachers that truly great teacher, Dr. E. J. Berg. He loved his boys and worked hard with them to bring to them a realization of the wonders of nature and of the opportunity that lay ahead for those who could visualize phenomena and apply mathematics thereto, and thus achieve a final result having practical application. Those who are not familiar with his method I refer to the text, "Electrical Engineering," by Berg and Upson. This book is full of what I have been saying, and I know its great power from my own practical experience.

One of the most fascinating problems was that of the short-circuiting of an a-c generator. I can see Dr. Berg to this day, as he stood at the blackboard, describing to us the phenomena of short circuit: what happened during the transient period from the steady state of normal power operation to the steady state of short circuit, how the field current died down, how the flux decreased, what factors were affecting the induced electromotive force, and finally arriving at a differential equation which could be solved to obtain an equation to give the instantaneous value of the armature current. In this came a recognition of the phenomena to give data for obtaining the values of the integration constants which are so necessary. Then, after obtaining the final equation, substituting in the equation to find the values of the current under many different circumstances, and the results plotted on squared paper show the phenomena in all of their beauty as the curves unfold on the squared paper. All this involved hard work that required knowledge of the phenomena, knowledge of mathematics to write the equations, knowledge of mathematics to solve the equations, and more hard work to evaluate the phenomena as they appeared on the squared paper.

Vast mathematical machines do much of this work for us today, and do more than ever could be done by human calculation. Nevertheless, we must always remember that without the knowledge in the brain of the engineer and of the scientist of the phenomena and of the applicable mathematics—without the engineer behind and within and surrounding the machine—the machine cannot function. The output is multiplied only because the engineer, the scientist, the mathematician are there to prepare it for the machine originally and to use it after it comes from the machine. Without the engineer, the machine becomes just a machine.

There is no decrease in these fundamental needs; rather, there is an augmentation necessary. In every field there are still unsolved problems. The pressure for greater output, for more versatile and simpler performance, for greater efficiency, for lower cost, demands a better and keener understanding of the phenomena involved and a better and keener understanding of the mathematics which can be applied to the phenomena to produce the desired result. Those who hold the key to the unfolding of these truths to the youth of our land may glory in their past achievements and may gird themselves ever more faithfully to live to inspire in their students a love for these attainments which will bring to mankind the opportunity for greater productivity and greater happiness.

I firmly believe a good dose of this doctrine is what the world needs from our good friends in other than science and mathematics and engineering of our schools. Then there will be brought into the lives of men that appreciation of the laws of nature which the scientist and engineer and mathematician have: that one pays for what one gets and that one does not get something for nothing.

The Torques of the Synchronous Tie

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THE PERFORMANCE of a synchronous tie—that is, of a synchronized drive consisting of two induction machines with interconnected rotors—has been analyzed[1] in terms of the loci of the stator currents. The torques impressed upon the rotors of these machines by their revolving fields can be expressed in the form

$$\tau_{\text{leader}} = \tau_0 + (\tau_\pi - \tau_0)\sin^2\frac{\delta}{2} + \tau_k \sin\delta = \tau_m + \tau_s \qquad (1)$$

$$\tau_{\text{lagger}} = \tau_0 + (\tau_\pi - \tau_0)\sin^2\frac{\delta}{2} - \tau_k \sin\delta = \tau_m - \tau_s \qquad (2)$$

where the subscript "leader" applies to the machine whose induced rotor voltages lead in time the corresponding rotor voltages of the other machine (called "lagger") by the angle δ in electrical degrees.

The quantities τ_0, τ_π, and τ_k are functions of s which depend upon the constants of the general equivalent circuit of the tie. The quantity τ_m is the motor torque; $2\tau_m$ represents the over-all power transmitted through both air gaps into the rotors; if friction and windage are considered part of the loads, the sum of the mechanical powers delivered by both shafts is represented by $2\tau_m(1-s)$, while the losses in the resistances of the rotor windings and additional rotor networks are given by $2\tau_m s$. The quantity τ_s is the synchronizing torque. It is this term of the expressions for torque which, acting in opposite directions on the two rotors, acts to keep them in step. For $s>0$, τ_m and τ_{leader} are positive, while τ_{lagger} can be negative.

The two remote stations to be kept in synchronous operation consist in general each of a driver (prime mover or motor of any kind) and of a mechanical load with given torque-speed characteristics. For each station the algebraic sum of the prime mover and load torques and of the torque developed by the corresponding induction machine of the tie is zero; thus two equations are provided from which the unknown s and δ can be obtained. Such equilibrium equations can be written in various forms but are difficult or impossible to solve by algebraic means. A convenient procedure is suggested by the chart in Figure 1 in which $\tau_m=$ constant and $\tau_s=$constant are drawn in terms of the two independent variables s and δ. The motoring and synchronizing torque requirements T_m and T_s of the mechanical loads are known functions of s. Then $-T_m$ and $-T_s$ are plotted on the chart, and the values of s and δ are obtained from the intersection of these two plots.

In some instances the synchronous tie is required to act as a load divider to reapportion the burdens of the two drivers by means of adequate synchronizing torques, but not to contribute much net mechanical power. In such cases external rotor networks are not used. Approximate solutions for s and δ are found immediately if τ_m is neglected. The rotation of the air gap fields may be chosen to make either $0<s<1$ or $s>1$, and the latter kind of operation often is preferred as it generally gives larger values of τ_k, thus making it possible to reapportion larger load differences.

Sometimes only one station has a driver and the other station is turned only by the induction machine of the tie, which acts as a follow-up device. The burden of supplying the over-all mechanical power rests mainly upon the driver of the first station unless the motoring action of the tie is emphasized by the use of additional rotor networks (with operation at $0<s<1$). If the driver is provided with a governor fixing its speed, the determination of δ is immediate and elementary steady-state stability considerations apply.

Finally, both drivers may be missing. The induction machines of the tie in this self-synchronous operation are required to provide motoring action covering the total power need of the loads. Thus rotor networks are used, and the choice of their parameters involves compromises between motor torque and synchronizing torque requirements.

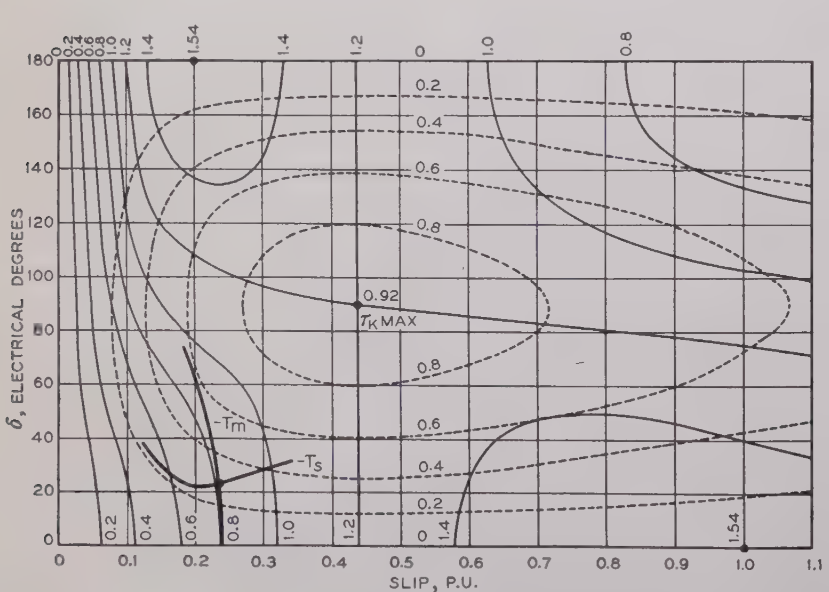

Figure 1. Chart for the determination of s and δ. Data were obtained for τ_m and τ_s constant

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Heat Transfer in Cable Ducts and Duct Assemblies

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STUDIES of heat transfer from cables in duct banks have indicated the need for more experimental data to establish thermal-resistivity values for several components of the duct system, particularly that portion of the heat flow path from the cable sheath to the outside of the duct wall. Theoretical considerations of heat transfer from the cable to the duct wall have treated the latter as an isothermal surface, and, generally, no consideration has been given to the effect of the thermal resistivity of the duct material. These approximations are made necessary in theoretical studies of cable systems by the complex geometry of the duct assembly, the cable sheath resting non-uniformly at the bottom of the duct. While such studies, supported by the experimental evidence available, yield reasonably accurate thermal resistivity values, the effects of a nonisothermal duct wall and of the thermal resistivity of the duct material can be taken into account by performing measurements on a duct assembly.

A study of heat flow in duct systems was carried out at the Johns-Manville Research Center to determine the thermal resistance of the components of the heat-flow path in a duct assembly. Tests were conducted on two types of laboratory duct installations, namely, ducts in air and a single duct encased in concrete. Transite and fiber duct, the latter possessing the higher thermal resistance, were employed in the tests, permitting a study to be made of the effect of the thermal resistivity of the duct wall upon the heat transfer from the cable sheath. Apparatus was designed for these tests to give accurate measurements of temperatures at many points on the duct installations and of the power dissipated in each duct assembly. Measurements were made under conditions of thermal equilibrium in a constant-temperature room, with the temperature of the lead sheath employed in the heating unit being held constant by a controller.

The temperature rise of the conductor of a cable above the average temperature of its outside duct-wall surface is given by the equation:

$$T_c=\left(R_{thi}+0.00411\,\frac{\beta}{D_s}+0.012\rho_d\log_{10}\frac{D_d}{D_i}\right)Q_c$$

where T_c is the temperature rise in degrees centigrade, R_{thi} is the thermal resistance from copper to lead in degrees centigrade per watt per linear foot, Q_c is the heat flow from the cable in watts per foot, and D_s, D_d, and D_i are the diameters in inches of lead sheath, outside duct surface, and inside duct surface respectively. The thermal volume resistivity of the duct material, ρ_d, in degrees centigrade centimeter per watt, is 480 for fiber and 200 for Transite, these values having been computed from the test data. The thermal surface resistivity factor for lead sheath in duct, β, in degrees centigrade square centimeter per watt, varies with the heat flow from the cable and the thermal resistivity of the duct-wall material. The three terms in parenthesis in the preceding equation represent thermal resistances of the cable insulation, the path from the lead sheath to the duct wall, and the duct wall, respectively. The temperature rise of the cable conductor above ambient air for the duct in air is obtained by adding the resistance term 0.00411 β_d/D_d to the equation, where β_d is the thermal-surface resistivity of the outer duct surface in degrees centigrade square centimeter per watt. For a duct bank, the thermal resistance term giving the temperature rise of the outside duct-wall surface above ambient earth is obtained from the working equations formulated by Neher.

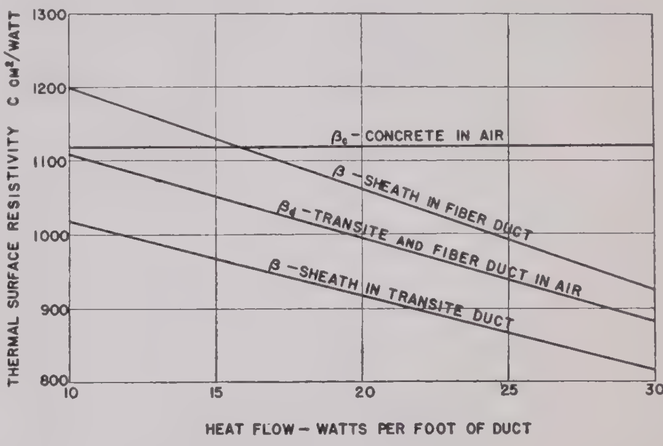

Figure 1. Thermal surface resistivity versus heat flow for lead sheath in Transite duct, lead sheath in fiber duct, outer duct surface in air, and outer concrete surface in air

Figure 1 shows thermal-surface resistivity values for various duct-assembly components versus heat flow, based upon average test values. Employing the values extrapolated to ten watts per foot of duct, we obtain β factors of 1,200 for fiber and 1,020 for Transite and a β_d factor of 1,110 for both duct materials. These resistivity values may be employed for current-rating calculations on cables in Transite or fiber duct, using maximum conductor temperatures specified by accepted industry standards.

Further tests on various duct materials should be of great value to cable engineers in establishing duct constants for these materials. Also, a more complete investigation is needed of the thermal resistance of the heat flow path from the cable sheath to the outside of the duct wall.

Digest of paper **50-55**, "Heat Transfer Study on Power Cable Ducts and Duct Assemblies," recommended by the AIEE Committee on Insulated Conductors and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 30–February 3, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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General Theory of Multiple-Cage Induction Motors

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POWER COMPANIES are usually particular about the starting current and running power factor of an induction motor. However, induction-motor manufacturers cannot possibly supply a motor much better in these respects than the present National Electrical Manufacturers' Association Design *C* standards, even though ideal materials should be discovered in the future.

Both the primary resistance and the saturation effect on leakage reactance are neglected in this analysis. While the first assumption can be fulfilled only with idealized material, it is a close enough approximation in motors of 20 horsepower or above. Under the assumptions, the motor can be analyzed with the help of a well-known theorem which states that as soon as the imaginary component of a physical network function is known for all values of frequency, the real component is totally determined up to an additive constant. In this case, the input reactive volt-amperes is the real component; the torque in synchronous watts the imaginary component; the slip corresponds to frequency; and the magnetizing current is the additive constant.

Figure 1 shows the assumed torque as a function of slip. Figures 2 and 3 show the full-load power factor and starting kilovolt-amperes per horsepower as functions of full-load slip and $k_{r\infty}$. The basic leakage factor $k_{r\infty}$ is defined as $1-X_\infty/X_0$ where X_∞ is the leakage reactance not including the slot leakage of inner cages and X_0 is the total reactance. Since no special configuration or multiplicity of rotor slots is assumed, the result indicates that the best obtainable starting current and full-load power factor are fixed as soon as the full-load slip is chosen. Since the value of $k_{r\infty}$ is not influenced by the selection of inner cage dimensions, altering the inner cage design would not improve the starting current and power factor without lowering the torque curve in general or in part. Real improvements can be accomplished only by measures which increase $k_{r\infty}$, such as reducing the air gap, increasing the number of stator slots, and so forth. All of these measures have practical limitations.

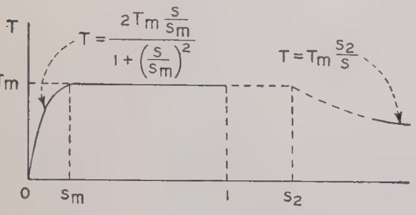

Figure 1. The speed-torque curve of a constant-torque motor

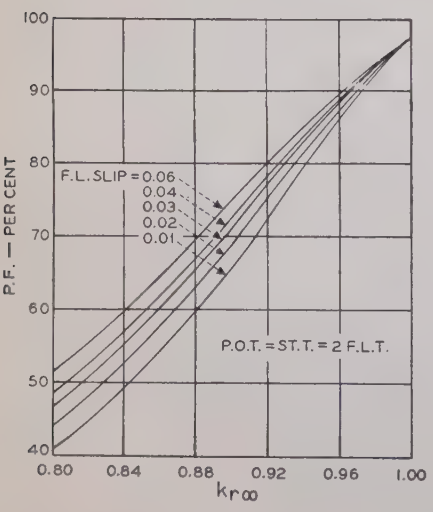

Figure 2. Power factor of a constant-torque motor as a function of full-load slip and $k_{r\infty}$

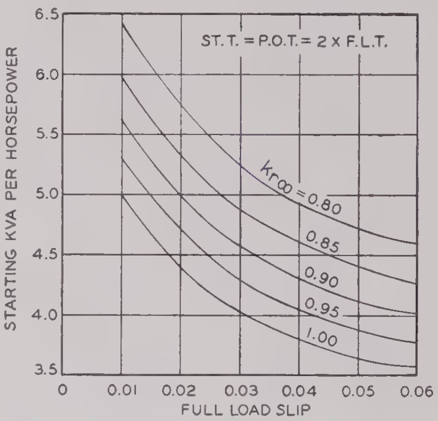

Figure 3. Starting kilovolt-amperes per horsepower of a constant-torque motor as a function of full-load slip and $k_{r\infty}$

The theory also provides a guide for designing rotor laminations. Let X_d be the total leakage reactance at no load, R_∞ be the rotor resistance of the outermost cage only, and R_d be the rotor resistance with all cages in parallel. X_d, R_∞, and R_d are determined by equations 1, 2, and 3.

$$\frac{X_d}{X_\infty}=\frac{}{\pi}\left(2.57+\ln\frac{s_2}{s_m}\right) \tag{1}$$

$$\frac{R_\infty}{X_\infty}=\frac{X_\infty}{X_d}\frac{s_2}{2} \tag{2}$$

$$\frac{R_d}{X_\infty}=\frac{X_d}{X_\infty}s_m \tag{3}$$

In these equations, s_m is the slip at maximum torque point and is about equal to 3.73 times the full-load slip; s_2 is the slip at which the torque tapers off. The value of s_2 is usually in the range of 1.5 to 2.5. The value of s_2 is chosen to compromise the full-load power factor and starting current. Both are lower for higher value of s_2 and conversely.

The values of R_d and R_∞ determine the total slot area and the slot area of the outermost cage, respectively. X_d determines the combined slot constant of the inner cages. Though all these conditions do not completely determine the slot shape, they are more than a starting point.

Digest of paper **49-238**, "General Theory of Multiple-Cage Induction Motors," recommended by the AIEE Committee on Rotating Machinery and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cincinnati, Ohio, October 17–21, 1949. Published in AIEE *Transactions*, volume 68, 1949, part 2, pages 1139–43.

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Gaseous-Conduction Phenomena and Their Application in Electrical Engineering

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Devices using gaseous-conduction phenomena in their operation play an important part in the field of electrical engineering. More than $500,000,000 worth of this type of equipment is being manufactured yearly, and it is being used for various purposes from Geiger counters and ionization gauges to fluorescent lamps and arc furnaces.

THE PURPOSE of this article is to present a brief survey of gaseous-conduction phenomena and of their relation to engineering in order to serve as an introduction to the more detailed articles covering the latest developments which are to follow in this series.*

In the course of this discussion, figures from the United States Department of Commerce Census of Manufacturers for 1947 are given to indicate the magnitude of some of the larger applications in this field. That the total manufactured value of discharge devices and associated equipment is in excess of $500,000,000 is evidence of the importance of the subject.

Gaseous-conduction phenomena can be divided into two general divisions: the non-self-sustaining discharges in which the discharge current is dependent on the presence of an external exciting agent, such as photo-ionization; and the self-sustaining discharges in which, once started, the current depends only on the circuit and discharge parameters. The transition between these two discharge types is termed a spark. Both types of discharges have low- and high-pressure aspects as well as numerous overlapping subtypes.

NON-SELF-SUSTAINED DISCHARGES

GASES completely shielded from radiation of all kind would be good insulators. However, light and penetrating radiations, such as from cosmic rays and from the radioactivity of the earth, continually produce ions in gases at a rate of from one to seven ion pairs (positive ion plus electron) per cubic centimeter per second at atmospheric pressure. The ions thus formed are being lost continually by recombination and diffusion to solid surfaces where neutralization takes place. The instantaneous ion density is usually governed by the relation:

$$\frac{dn}{dt}=q-\alpha_r n^2+D\nabla^2 n \qquad (1)$$

where n is the density of ions of a single sign (there being an equal number of the opposite sign), q is the rate of production of ion pairs, α_r is the recombination coefficient, and D is the diffusion coefficient appropriate to the diffusion of an ion cloud through the neutral gas. For air at standard temperature and pressure, the value of D is about 0.035 centimeter squared per second. The net effect in free air at standard conditions for $q=6.4$, $\alpha_r=1.6\times10^{-6}$, and diffusion neglected is the maintenance of an average ion density of 2,000 ion pairs per cubic centimeter. When a weak electric field E is applied to an ionized gas, the ions gain energy from the field in their free paths and then have this energy scattered by collision with neutral atoms. These ions will have an average drift velocity parallel to the direction of the field given by

$$v=KE \qquad (2)$$

where K is known as the mobility. The mobility depends on ion, gas, and gas density. For air at standard temperature and pressure, it is about two centimeters per second per volt per centimeter.

The non-self-sustaining discharges can be best illustrated by considering two electrodes in a gas at a reduced pressure, for example, one millimeter of mercury. With ultraviolet light shining on the cathode, the voltage across the electrodes is varied (and the current in the external circuit is observed). The result is as is shown in Figure 1. In the region of low voltages T_0 the current from the initial photoelectric emission of electrons at the cathode increases with the voltage. Saturation is quickly produced with all emitted electrons reaching the anode as i_0. Further increase in voltage soon results in a region of increasing current T_1. This is known as a Townsend discharge and is the simplest form of gas amplification of current. In the Townsend discharge, an electron is accelerated by the electric field until it gains sufficient energy to ionize a gas atom with which it collides. The process of ionization brings into being a new electron and a positive ion. The two electrons are quickly swept away by the field for fur-

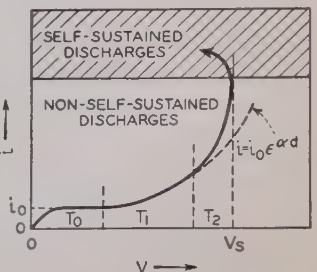

Figure 1. Current-voltage relations in prespark regions with ultraviolet light shining on the cathode

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Full text of a conference paper presented at the AIEE Winter General Meeting, New York, N. Y., January 30–February 3, 1950.

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* This is the first in a series of four articles covering various phases of gaseous-conduction phenomena.

ther ionizing collisions, and the positive ion, being very heavy compared to the electron, moves slowly towards the cathode with a velocity determined by its mobility. For a uniform field the number of electrons produced by one initial electron increases exponentially with distance from the origin of the first electron. This amplification of a single electron is called an electron avalanche. In the Townsend discharge in a uniform electric field, the current increases exponentially with the gap separation as

$$i = i_0\epsilon^{\alpha d} \tag{3}$$

where i_0 is the initial photoelectric current from the cathode and d is the electrode separation; the coefficient α is known as Townsend's alpha. Townsend's α is given to a fair approximation for many gases by

$$\frac{\alpha}{p} = A\epsilon^{-B/(E/p)} \tag{4}$$

where A and B are constants appropriate to the gas, E is the electric field, and p is the gas pressure. More accurate empirical relations are known for limited ranges of E/p. Gas-filled photoelectric cells operate in the Townsend discharge region. As the voltage across the electrodes is further increased, a region T_2 is reached where the current increases more rapidly than is possible by the simple electron multiplication mechanism. This may be called a Townsend discharge of the second kind to distinguish it from the first. The electric field has now become great enough so that some of the positive ions arriving at the cathode have sufficient energy to cause the ejection of an electron. In this region, the current is given by

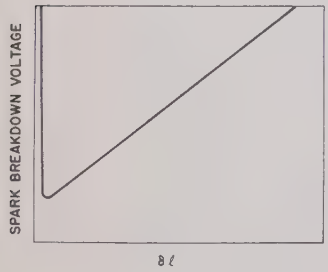


Figure 2. Spark breakdown voltage as a function of gap length and gas density illustrating Paschen's law

$$i = \frac{i_0\epsilon^{\alpha d}}{1 - \gamma\epsilon^{\alpha d}} \tag{5}$$

where γ is the number of electrons released per incident positive ion. Other emission processes are active in this region and are included in γ, but positive ion bombardment is usually the most important. Eventually di/dv becomes infinite, and a spark results in the transition to one of the self-sustaining discharges. For long gaps at high pressures where a long time is required for positive ions near the anode to cross the gap, the breakdown develops as a streamer from the anode which in effect moves the anode potential closer to the cathode. The point of the streamer grows rapidly towards the cathode as new electron avalanches, started by photo-ionization from the streamer, feed into it. Similar streamers may appear at the cathode, especially for negative points, and sometimes develop in the mid-gap region. The phenomena associated with the spark discharge formation are important in practice where impulse voltages are to be measured or protected against. These formative processes determine the time lag of breakdown and, consequently, the overvoltage that may appear at the gap.

The spark discharge voltage is a function of the product of gas density δ and gap length l. This relation, known as Paschen's law, is shown in Figure 2 for a uniform electric field. This relation holds over a very wide range of gas density. The use of test and protective gaps, horn gaps, and so forth are too well known to discuss here, but some special applications are of interest. The low-density portion of the Paschen curve has its greatest interest in connection with the starting of low-pressure discharge lamps. However, with the increasing number of missiles probing the upper atmosphere and other high-flying machines, the low-density portion of the Paschen curve is important to designers of electronic equipment, since flashover may take place at low voltages when the altitude results in the minimum δl. Below the minimum δl, breakdown may occur over a long path rather than at the point of closest approach.

Certain gases such as chlorine, freon, sulphur hexafluoride, and so forth have a strong affinity for electrons. When these gases are present in small amounts, they will quickly attach any free electrons present. This increases the voltage at which electron avalanches may develop into breakdown of the gap. For example, the dielectric strength of $C_2Cl_2F_4$ at its saturated vapor pressure of 23 degrees centigrade (two atmospheres absolute) is 5.6 times that of nitrogen at standard temperature and pressure. The use of these gases, pure or as admixtures, at high pressures is increasing for high-voltage equipment.

Among the applications of the non-self-sustained discharges are to be found such devices as Geiger counters, gas-filled photoelectric cells, and ionization gauges.

SELF-SUSTAINED DISCHARGES

The self-sustained discharges may be identified by referring to Figure 3. The voltage drop across these discharges depends on the current flowing, so that current is given as the independent variable, rather than voltage as was done in Figure 1. The spark at S marks the transition from the Townsend discharge to either a glow or arc discharge depending on the voltage and circuit impedance.

Corona. If one of the electrodes produces a strongly divergent electric field, an incomplete breakdown called a corona discharge results near S. Corona is important in all high-voltage apparatus, where it not only represents a power loss but it also facilitates flashover and promotes the destruc-

Figure 3. Characteristics of self-sustained discharges

Point S marks the transition from the Townsend discharge to glow or arc discharges

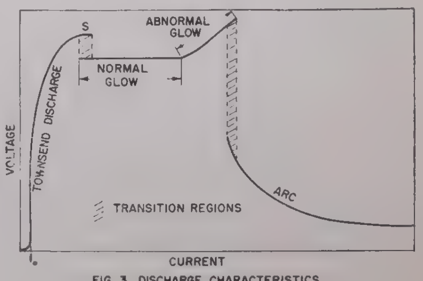


FIG. 3 DISCHARGE CHARACTERISTICS

tion of insulating materials. Voids within insulation are subjected to ionization phenomena, much like corona, which accelerate the aging of the insulation of high-voltage transformers, alternators, and so forth. Corona discharges produce interference in both radio and telephone circuits that can be very objectionable. The corona discharge is used in precipitation apparatus.

Glow. The glow is a luminous discharge usually occurring at pressures less than 0.1 atmosphere, with low currents and moderate voltages. The glow is characterized by two principal luminous regions; one is near the cathode and is known as the negative glow, while the other occupies most of the region between negative glow and anode and is called the positive column. Between the cathode and the negative glow is a dark space called the Crooke's or cathode dark space. This is a positive-ion space-charge region in which positive ions formed in and near the negative glow drift towards the cathode and must be accelerated sufficiently by the resultant space-charge field to reduce, by bombardment of the cathode, sufficient electrons to sustain the discharge. The voltage drop in this region is of the order of 100 volts, and it depends on the gas and electrode material. At low currents (of the order 1 to 75 milliamperes), the glow is essentially a constant-voltage discharge, called the normal glow (Figure 3), and is used as a voltage regulator element in electronic circuits in the form of voltage regulator tubes. When the current reaches a critical value, the cathode becomes completely covered by the glow, and a further increase in current results in a rising voltage-current characteristic, the abnormal glow region (Figure 3). The light from the negative-glow region is the principal source of light in the glow lamps used for indicators. The positive column may be quite long and has a voltage gradient of the order of 1.0 volt per centimeter. The column is a typical plasma with the electron and positive-ion densities almost equal. The light from this region is used in luminous signs. Another important application of the glow discharge is found in small 3-electrode tubes which can be used for control purposes where freedom from the cathodes heating requirements of the hot cathode control tubes is desirable.

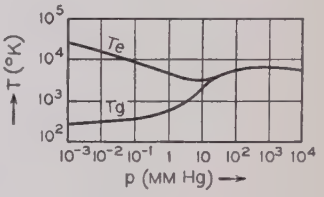
Arcs. The arc discharge is probably the most important of all the discharge forms to engineers. This is true because of the monetary value of arc equipment of all kinds in use and being manufactured, as well as because of the importance of the operations performed by this equipment.

The arc is, in general, a low-voltage high-current discharge. The current may range from a fraction of an ampere to thousands of amperes. The voltage drop at the cathode of arcs is of the order of the least ionization potential of the gas or vapor in which the discharge burns. Since the first ionization potentials of the elements vary from 3.87 electron volts for cesium to 24.46 electron volts for helium, it is evident that the process of electron emission from the cathode must be far more efficient than is present in the glow discharge where the cathode drop ranges from about 75 to 400 volts.

When the current in the abnormal glow region (Figure 3) is increased, a critical value is reached at which a sudden transition between glow and arc takes place. The cathode current density increases to a relatively high value, and the discharge column at moderately high pressures becomes quite bright. For refractory cathodes such as wolfram (tungsten) or carbon, the cathode-spot current density is usually of the order of 500 amperes per square centimeter. These electrodes are kept incandescent by positive-ion bombardment, heat of association of atoms from the column, and radiation from the column, as well as contact with high-temperature neutral gas atoms, and the electron emission is supplied by thermionic emission. This is the same emission mechanism as exists when the cathode is maintained at a high temperature by a heater which is separate from the discharge.

A different type of cathode spot, having a current density of greater than 50,000 amperes per square centimeter, exists on lower boiling point metals. This spot is highly mobile compared to the fixed spots of a thermionic arc, and has the interesting property in certain pressure ranges of moving in a direction contrary to the ponderomotive force when in a transverse magnetic field. Neither the mechanism of emission nor of its retrograde motion is understood. The mechanism of this type of cathode is variously ascribed to field emission, to thermionic emission from a zone at temperature far above the normal boiling point of the cathode material, and to thermal ionization producing sufficient positive ions near the cathode surface to carry the entire current. Each of these theories has rather serious limitations. An important characteristic of most of the cold-cathode arcs is the necessity for some oxide to be present on the surface. Recent researches on this subject have shown the cathode-spot current density to be higher than had previously been believed. For very short-time arcs, the cathode-spot current density may be as great as 10^6 amperes per square centimeter.

Figure 4. Dependence on gas pressure of electron temperature T_e and gas temperature T_g in electric arc (mercury arc at constant current)



The characteristics of the arc column or plasma depend on the gas pressure. At low pressures, the column is diffused, the electron temperature is high, and the gas temperature is relatively low, while at high pressures the gas and electron temperatures are about equal and of the order of 6,000 degrees Kelvin. Figure 4 shows schematically the electron and gas temperatures of an arc column as functions of the pressure. The point where the electron and gas temperatures are roughly equal may be considered as the division between low- and high-pressure phenomena of arcs. The high gas temperature of the high-pressure column produces a high degree of dissociation of polyatomic gases.

Since thermal equilibrium exists among electrons, positive ions, and neutral gas particles in the high-pressure-arc column, Saha's equation is considered to hold with sufficient accuracy in most cases. The Saha equation relates the electron density n_e, positive-ion density n_i, and neutral gas atoms n_n to the ionization potential V_i of the gas and the temperature T as,

$$\log_{10}\frac{n_e n_i}{n_n}=\frac{-5{,}050\ V_i}{T}+1.5\log_{10}T+15.385 \qquad (6)$$

This relation does not take account of the various losses such as radiation (perhaps 15 per cent), convection, and so forth which occur in arcs, and becomes quite complicated when mixed gases are present. The gradient at low pressures is of the order of a 0.1 volt per centimeter or less, while at high pressures it is usually greater than 10 volts per centimeter. At low currents, the column current density is in the range of 6 to 60 amperes per square centimeter. For currents in excess of about 150 amperes, the column current density may be as great as 3,000 amperes per square centimeter due to the action of the arc's magnetic field in constricting the column. Although it is often stated, as an oversimplification, that the arc column is maintained by thermal ionization, the fact is that the column is maintained by electric energy given to the electrons of the plasma by the column gradient. The ionization in the high-pressure column is produced by the combined action of electron collisions, photo-ionization, and collisions of high-speed neutral particles. The latter process probably becomes very important at very high pressures.

Solids inserted into an arc column receive thermal energy from: the kinetic energy of gas atoms striking the surface; the heat of association of dissociated polyatomic gases that recombine on the surface; radiation from the excited gas in the column; and heat of neutralization of positive ions and electrons recombining on the surface. Often the heat of association constitutes the greater part of the energy received. The total energy radiated from an arc amounts to not more than about 20 per cent of the total energy loss.

The anode serves to collect current from the arc plasma as required by the circuit. At high pressures the temperature of arc anode spot is usually at the boiling point of the anode material. This results in the vaporization of much anode material, which, since it may pervade a considerable part of a short arc column, can change the arc column from a gas to a vapor arc. This is true because the ionization potential is of the order of 15 volts for most gases and of the order of seven volts for most metals, and the gas of lower ionization potential has the greatest degree of ionization. Since the heat of condensation of electrons is added to the energy electrons gain in falling through the anode drop of potential, the anode spot is heated to a higher temperature than is the cathode spot where evaporation of electrons has a cooling effect.

Some of the more important applications of electric arcs follow.

Rectifiers and Control Tubes. Large power rectifiers constitute a very important type of arc discharge device in industry. The total installed capacity of these rectifiers in the United States and Canada is about 5,500,000 kw. The smaller types of gas and vapor rectifiers and control tubes of all kinds are equally important, for the value of these manufactured in 1947 was $4,478,000.

Arc discharges between markedly dissimilar electrodes such as a large, cold graphite block and a hot filament have the property of rectifying current. This is because the filament supplies a copious electronic current when it is cathode, while a cathode spot cannot be easily formed on the cold graphite when the voltage reverses and the graphite electrode becomes negative. Addition of a grid permits the average rectified current to be varied by application of a negative voltage which prevents conduction even though the anode is positive. Rectification also takes place when the filament is replaced by a mercury pool. Usually mercury vapor is also the conducting medium. In this case, a cathode spot must either be maintained on the pool by an auxiliary d-c arc (or by current to other anodes of different phase in a multianode tank) or else started each cycle by a synchronous starting device. Usually the cathode spot of single-anode rectifiers is started by an immersion ignitor of moderately high-resistance material, such as boron carbide, through which a pulse of current is passed at the proper phase. The arc cathode spot is then established on the mercury surface at or near the ignitor due either to the high local electrostatic field or to the establishment of a high local temperature with mercury vaporization and the breaking of local contacts with resulting formation of small arcs. The variation of the phase at which the ignitor pulse is applied permits the rectified current to be varied by the ignitron in accordance with load requirements.

Large power rectifiers have numerous advantages over rotating machinery, such as: they are static equipment; they are easily switched off and on; they are relatively independent of frequency and system disturbances; faults are easily cleared; a relatively high efficiency is obtained over most of the load range; operating and maintenance costs are usually lower than for rotating machinery. The single-anode rectifier is largely displacing the multianode rectifier because of its simpler maintenance, lower arc drop, and ease of manufacture. The sealed tubes are usually limited to a maximum of 1,000 kw, with larger sizes being continuously pumped to remove foreign gases from the mercury vapor which is the primary conduction medium.

The hot-cathode grid-controlled rectifiers, or thyratrons, have many applications in power electronic devices. Usually the conducting medium is mercury vapor, but inert gases such as argon, krypton, and xenon are used where temperature independence is desired. Where very rapid deionization is required, as in high-power pulse modulators for radar, hydrogen is used. Many of the hot-cathode thyratrons generate noise and oscillation voltages of considerable amplitude. These phenomena were used in the modulators of radar-jamming transmitters in the last war.

Circuit Interruption. All the electric power used flows through many circuit breakers, fuses, contactors, switches, and so forth, before reaching its ultimate load. The importance of circuit-interrupting devices is almost too well known by electrical engineers to require elaboration. However, it is interesting to note that in 1947 the value of switchgear and switchboard apparatus was $360,988,000, of which circuit breakers amounted to $69,059,000, while the value of all kinds of fuses was $20,698,000.

An arc is inevitably formed whenever a circuit carrying current is interrupted, except for the special case of synchronous opening of contacts at the instant of zero current in a-c circuits. If the arc did not exist, it would be necessary to invent its equivalent in order to prevent excessive voltages appearing in inductive circuits upon the sudden interruption of current. The papers and discussions appearing in the AIEE *Transactions* of the arc-extinction characteristics of various devices are filled with many vigorous and conflicting claims as to the arc processes involved in particular devices.

Basically, the action of any switch is to deionize the highly ionized column of the arc as rapidly as possible. This is done in a number of ways: by introducing cold neutral gas which absorbs energy from the column and lowers its temperature as well as providing turbulent zones for the rapid attachment of electrons and accelerated recombination of the ions; by the introduction of liquids, the vaporization of which absorbs large amounts of energy and which provide a spray of particles which increase the effective wall area to the column for the surface recombination of ions; by introducing solid or liquid barriers, which increase the rate of neutralization by providing area for surface recombination of ions so as to remove heat energy rapidly and also usually lengthen the arc path.

In general, d-c switches operate in such a way that the arc drawn upon opening the contacts quickly requires more voltage for its maintenance than is available in the circuit so that extinction follows. This is done by increasing the energy loss in the arc by lengthening the column by mechanical motion of contacts, magnetic blowout, convection lengthening in a horn gap, or by a gas blast.

In the interruption of alternating current, the very brief interval in which the current is substantially zero is very helpful in effecting circuit interruption. Short gaps have been found to recover a strength of several hundred volts in a few microseconds as a consequence of the neutralization of the space charges in the cold-cathode and anode-drop zones at the surfaces of the contacts. By breaking the arc up into a series of short arcs, each of which has this rapid recovery of several hundred volts, the switch can very rapidly resist a rather high value of recovery voltage. The introduction of cold gas is usually effected by either a magnetic blowout, which continually moves the arc column into unionized zones, or by a gas blast supplied from a piston or compressed-air tank. In the air circuit breakers, the gas blast may be transverse to the column or it may be longitudinal with expansion zones to cool the hot gases. The vacuum switch is a rather special type in that the arc burns entirely in metal vapor formed by the vaporization of the last point of contact and by continued vaporization from the contacts. When the current equals zero, this vapor ceases to be supplied by the action of the arc anode and cathode spots and that vapor which is present in the column zone diffuses away with great speed leaving nothing to carry current.

Except for the lowest voltage applications, fuses operate with the fusable element in either a gas-forming solid or in a finely divided refractory solid material. In the first case, the arc is extinguished by the high recovery strength of a moderately high-pressure gas combined with the turbulence produced by the rapidly evolving gas. In the second type of fuse, a very large surface area is provided for rapid deionization of the column by surface recombination.

Welding. Arc welding is an important manufacturing and fabricating application of gaseous conduction as evidenced by the fact that in 1947 the annual production of electrodes was 382,433,000 pounds, valued at $43,987,000, while the value of arc-welding machines produced was $32,110,000.

From the standpoint of gaseous-conduction phenomena, the simplest form of arc welding is the inert-gas type. In the inert-gas arc welding, the electrode holder, or torch, is provided with a nonconsumable tungsten electrode and a nozzle so placed as to blanket the electrode and the arc with a continuous flow of either argon or helium. When the electrode is operated negative with direct current (straight polarity), the electrode size must be so adjusted that the end operates incandescent to provide the arc current by thermionic emission. Too large a rod will not be heated sufficiently by the discharge, and an unstable, nonthermionic arc cathode spot will result. An electrode too small in size will result in melting of the tungsten and contamination of the work. The energy received by the anode (work) is the current times the sum of the anode drop plus the work function of the metal, plus such energy as is radiated from the column. The action of a cathode spot in following and destroying an oxide layer is used in the welding of aluminum where alternating current is used. When the aluminum is negative, the cathode spot cleans an area free of oxide which is then welded by the anode heat on the next half-cycle.

In welding with consumable electrodes, as for example with a coated-iron electrode, the phenomena are complex and often not understood. The boiling points of the metals are too low to supply the heavy currents used by thermionic emission in the usual sense. However, most coatings which are used primarily to provide a suitable gas blanket for the arc column and the metal as well as to yield slags for the molten metal, often also provide oxides and low-work function impurities that tend to stabilize the cathode spot. Metal is transferred from the electrode by molten drops, evaporated atoms, the spray of small particles normally associated with anode and cathode spots, and by the action of oxygen that has diffused into the hot metal and combined with the carbon present in steel to form carbon monoxide, the expansion of which produces small explosions at the surface and consequent expulsion of metal. The latter effect is probably the most important factor in the transfer of metal in overhead welding. Welding with consumable electrodes is usually conducted with the arc burning in an atmosphere of polyatomic gases. These gases are usually dissociated to a high degree by the arc column. Thus, a considerable amount of heat received by both work and electrode is due to the arrival of atoms with the resulting release of their heat of association as the molecules are reformed. In the atomic hydrogen process of welding almost all of the heat received by the work is the heat of association of hydrogen dissociated in an arc burning between two tungsten electrodes in a stream of hydrogen gas directed at the work.

Arc Furnace. An arc furnace is a welding arc on a grand scale in which the metal to be melted is one electrode. In small units, the arc may be direct current, but in large units arcs are maintained between 3-phase electrodes with the melt connected to the neutral. The electrodes, which are usually of carbon, used in these furnaces had a manufactured value of $6,880,331 in 1947. The total annual capacity of electric furnaces is about 6,000,000 net tons of steel ingots, or about six per cent of the annual capacity of the United States.

Gas Discharge Lamps. Arc discharge lamps exist in many forms and include the highest intensity and the most efficient light sources yet developed. The manufactured value of discharge lamps of all types was $49,036,000 in 1947. Of this, $42,501,000 was represented by fluorescent lamps.

The carbon arc was one of the first practical electric lamps. In general, most of the useful light from the carbon arc comes from the positive crater. The principal improvement of modern arc lamps over the early ones is in the use of special core materials. Usually the positive core contains cerium compounds which vaporize and form a flame of incandescent cerium carbide particles at the anode crater. Fluorescent lamps usually have a low-current arc in a low-pressure mixture of mercury vapor and inert gas. The light from the 2,537-Angstrom line of mercury is most effective in exciting the phosphor coating on the inside of the glass. The sodium-vapor lamp is a low-pressure arc burning in a mixture of neon and sodium vapor. Because of the low ionization potential of sodium (5.13 electron volts compared to that of neon (21.53 electron volts), the normal discharge is supported entirely by the sodium atoms. The neon provides ready starting when the lamp is cold, but serves only to scatter low-energy electrons so as to increase their chance of striking a sodium atom when the lamp is hot. When these electrons gain 2.1 electron volts energy, they can excite the principal lines of the sodium spectrum. Commercial mercury-vapor arcs are built to operate at various pressures from a few millimeters of mercury to 80 atmospheres. The low-pressure lamps have the characteristic line spectrum of mercury with its red deficiency. As the pressure is increased above one atmosphere, a continuum appears that improves the quality of the light. The high-pressure lamps have the arc burning in a capillary and have been made to operate at pressures of the order of 100 atmospheres.

High-Frequency Discharges. In general, high-frequency breakdown, important in the construction of high-voltage high-frequency equipment, is lower than the d-c or low-frequency breakdown. An important application of these discharges is found in the transmit-receive box of a radar set used to protect low-power-level receiving elements of a radar set from the high-level power of the transmitted pulse.

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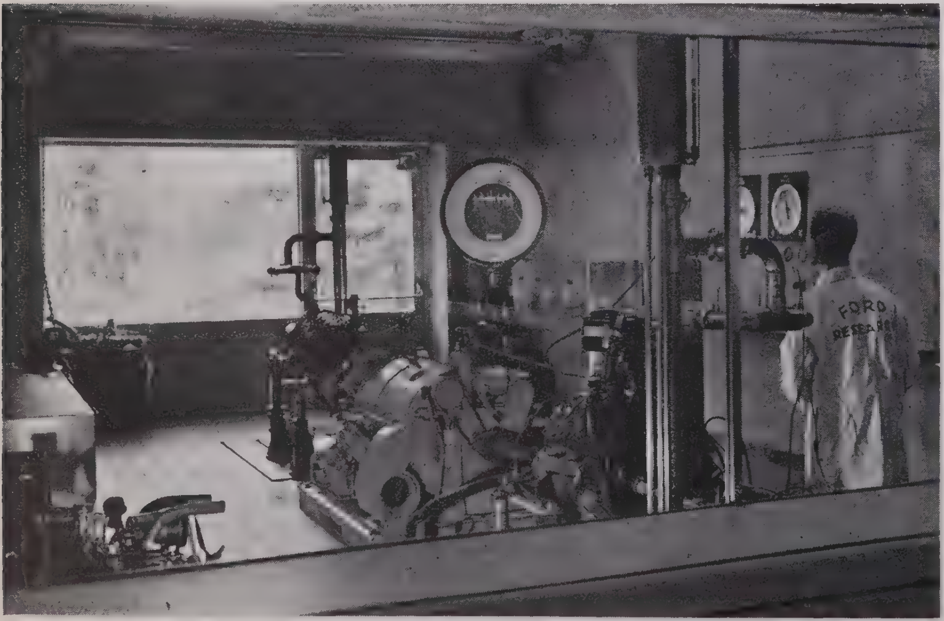
The Ford Motor Company's New Engine Development Laboratory



The Ford V-8 engine shown in the foreground of one of the soundproof test rooms of the Ford Motor Company's new engine development laboratory in Dearborn, Mich., is being tested with the 200-horsepower d-c amplidyne dynamometer acting as a brake to determine the horsepower of the engine on a performance run. At the left of the dynamometer is a Ford 6-cylinder engine which has been readied for testing when the V-8's run is finished. This view shows the double panes of plate glass which help make the 15 test rooms soundproof. At the upper left is a traveling crane for lifting and moving test engines into place anywhere in the room

Thermal Endurance of Class H Insulation

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A COMPREHENSIVE MOTOR test program was undertaken to determine the thermal endurance of Class *H* insulated motors at several different temperatures. A scattering of thermal life and points was obtained over a sufficiently wide temperature range to permit extrapolation of life expectancy to lower temperatures. A comparison was obtained between the behavior of Class *B* insulation and Class *H* insulation under the same test conditions. The fundamental concept followed in this test program is that appreciable decrease in the humidified insulation resistance of windings is a criterion of minimum motor insulation life.

The tests included six 10-horsepower induction motors with Class *H* insulation treated with *DC 993* silicone varnish and two Class *B* induction motors of similar design plus one traction motor with Class *H* insulation treated with *DC 993* silicone varnish. The test program began with a period of operation at elevated temperature followed by cooling to room temperature and exposure of the windings to 100 per cent relative humidity for a 24-hour period. Subsequently, each motor was operated at load to produce high operating temperature for an accelerated life test. The temperature of the various motors under test (as observed by resistance) range from 200 to 310 degrees centigrade. The motors were subjected to high humidity conditions periodically during their operation.

The results of insulation resistance and dissipation factor measurements before and after humidification show the effects of aging and humidification. In general, a similar pattern is obtained on each unit. The humidified insulation resistance and dissipation factor show little change in the earlier stages of aging. Then suddenly insulation resistance decreases and dissipation factor increases indicating a major change in the condition of the insulation. This is the point at which moisture begins to penetrate the winding and is considered to be the minimum insulation life point. It was observed that crazing of the resin surfaces becomes noticeable coincident with the loss of moisture resistance of the windings.

Another evidence of insulation aging is the increase in cold resistance of the winding due to oxidation of the copper. Abrupt changes are observed when the varnish film becomes permeable to moisture and air. The test results are interpreted to indicate that Class *H* insulation, employing *DC 993* silicone varnish, follows a rule of half-life for increments of 11.6 degrees centigrade. These tests further indicated that, for a 7-year minimum life, a temperature of 220 degrees centigrade should be permissible, in so far as the thermal aging of the insulation alone is concerned. Conclusions reached were:

1. This method of testing is a satisfactory way to determine the minimum thermal life expectancy of insulation in an electric motor. It also determines the type of failure to be expected from thermal aging of different kinds of insulation.
2. The minimum life points as determined by this method and serious crazing of the resin occur after the same amount of aging.
3. Failure of the windings of silicone-insulated motors has been found to occur before the bonding of the resin is seriously weakened and was due to copper conductor failure.
4. Silicone insulation presents less fire hazard than do other classes of insulation as shown by these tests and other independent flammability tests.
5. When motors of this size operate at temperatures near 280 degrees centigrade, the number of times they are cooled will affect the minimum life. More frequent thermal cycling may reduce the minimum life.
6. The minimum thermal life of Class *H* insulated equipment using *DC 993* varnish is approximately twice that of equipment made with *DC 990A* varnish.
7. The results of these tests indicate about a 100-degree-centigrade temperature advantage for Class *H* insulation compared with Class *B* insulation. If current concepts of thermal aging are correct, the Class *H* insulation could be expected to operate as much as several hundred times as long as Class *B* equipment, where thermal aging is the primary factor in establishing insulation life.
8. At least seven years of continuous operation at a hottest spot temperature of 220 degrees centigrade will be required to reach the minimum thermal life of Class *H* insulated equipment.
9. The thermal life of Class *H* silicone-insulated motors closely follows a 12-degree-centigrade rule. It is possible that the life of Class *H* insulated equipment, employing *DC 993* silicone resin, may follow the more optimistic rule,

$$\text{Log}_e\ (\text{hours life}) = \frac{16{,}520}{\text{Absolute Temperature}} - 23$$

10. The maximum life of Class *H* insulation was not determined by these tests, since the ultimate end points were the results of copper conductor failure rather than mechanical disintegration of the resin.
11. In silicone-varnished Class *H* motors, insulation resistance as a function of relative humidity can be used effectively in maintenance work. If the insulation resistance is not seriously affected by humidity, the motor may be presumed to be entirely satisfactory for continued use. If dependent on humidity, the minimum life point has been reached.

Digest of paper **49-237**, "Motor Tests Evaluate Thermal Endurance of Class H Insulation and Silicone Varnish," recommended by the AIEE Committee on Rotating Machinery and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cincinnati, Ohio, October 17–21, 1949. Published in AIEE *Transactions*, volume 68, part 2, pages 1133–8.

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Report on Tidd 500-Kv Test Project

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The field test project for studying corona, radio influence, and other technical features of electric power transmission in the extra-high-voltage range has now been in progress on the Ohio Power Company system of the American Gas and Electric Company at Brilliant, Ohio, for over two years. This article is a progress report of this activity.

DURING the past two years a great deal of information of value on the technical features of high-voltage line design has been obtained from the field research which is being carried out by the American Gas and Electric Service Corporation in co-operation with eight manufacturers of high-voltage equipment, which was fully described in a symposium of seven technical papers presented before the AIEE.[1–7] The objectives and the test facilities used for carrying on the field test work were covered in considerable detail in that series of technical papers.

In brief, the test facilities consist of a 5,000-kva bank of three single-phase transformers which can vary the 3-phase line-to-line voltage in steps from 265 to 530 kv. Three test lines, two 1.4 miles long and one 800 feet long, are available. Supersensitive metering equipment is used to indicate and record corona loss. The metering also includes indicating and graphic radio-influence meters, commercial amplitude-modulated and frequency-modulated receivers, a television set, a voltage gradient meter,[8] and graphic meters to record temperature, barometric pressure, precipitation, and humidity. In addition, an automatic camera, set to photograph sample conductors and insulators every 20 minutes, is used in the determination of general weather conditions, such as rain, snow, sleet, and fog. A setup is also provided to measure the loss on a string of insulators. Line conductors measuring from 0.92 inch to 2.0 inches in diameter have been tested as well.

The great amount of data already obtained from the field tests has been partially analyzed but still requires further study and correlation before arriving at definite conclusions. However, it was felt that although the analysis and field test work are not complete at this time, a presentation of the progress being made and some of the high points of the results obtained would be of interest now. It is planned within the next year to follow this brief presentation with more complete results and analysis. It needs to be emphasized, therefore, that the data presented here must be considered as preliminary; complete analysis of data already obtained and further work now in progress may modify the results.

In the corona-loss studies emphasis has been placed on establishing a method of estimating the magnitude of the annual corona loss on various conductor and line designs and the manner in which the corona loss may be expected to vary with voltage and weather. Information upon which to base estimating procedures can well be obtained by recording the corona loss on a full-scale line at different voltages over long periods that include all kinds of weather. The corona test program has been planned in order to obtain the fundamental data required to meet these objectives.

Because of the many variables involved, and the fact that weather conditions cannot be controlled, the procedure was adopted of recording, for later analysis, those factors which are considered important, rather than depending upon making individual tests under a variety of weather conditions. Figure 1 illustrates typical information that has been thus obtained or can be derived from the field graphic charts.

The lines were energized continuously, and the applied voltage was changed every few days. Voltages of 280, 345, 396, and 452 kv phase-to-phase have been used. In addition to obtaining graphic records of corona loss at these four voltages, voltage versus corona power loss runs were made every four weeks, using indicating instruments. These tests were made under both single- and 3-phase conditions. Most voltage runs were made under fair weather conditions so that the results of successive tests could be compared. Some tests under adverse weather were made.

Great variance was observed in corona loss measurements as noted by previous investigators.[9–13] The factors influencing this variance can be divided into two categories: first, those associated with the conductor surface, and second, those associated with weather conditions. Thus different conductors might have comparable corona loss under fair weather conditions, but they might have completely different losses after aging or during a spell of foul weather.

The surface of an energized conductor undergoes a change with time such that the loss usually decreases, the magnitude of the change varying with the particular type of conductor. From the fair-weather runs made periodically over a period of almost two years, the loss values corresponding to the 532-, 454-, and 376-kv points are plotted in Figure 2 for the 1.65-inch Henderheim (HH) conductor. This figure shows how much loss might be expected on a new conductor when it is first placed in service.

The effect of continuous energization of the conductor

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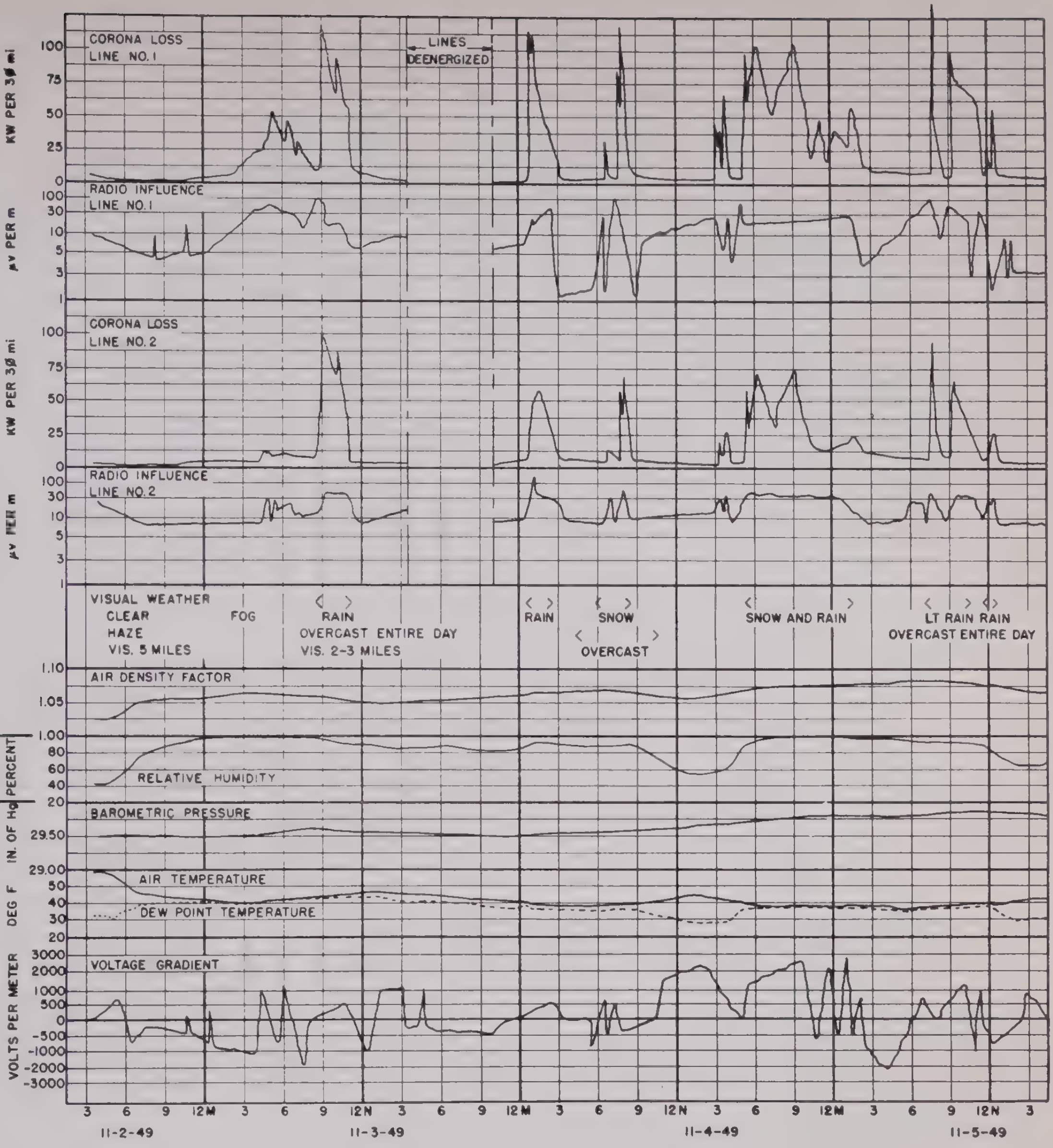

Figure 1. Typical correlated graphic data on corona loss, radio influence, weather, and so forth, obtained or derived from continuously recorded field measurements. The test lines were here energized at 454 kv line-to-line

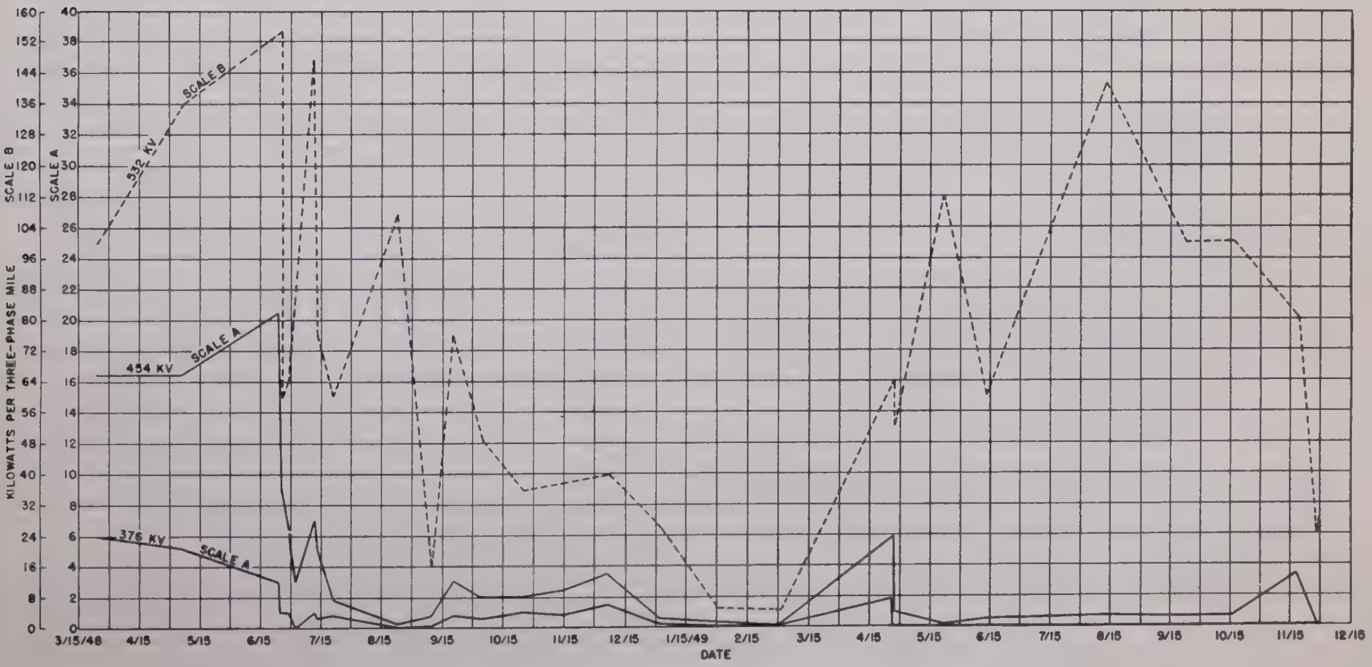

Figure 2 (below). Change in corona loss of a conductor at phase-to-phase line voltages of 376, 454, and 532 kv during fair weather over a period of almost two years. The conductor spacing was 45 feet until July 18, 1949; thereafter it was 32 feet

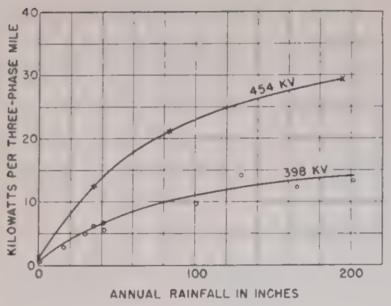

Figure 3. Correlation between rate of rainfall and corona loss, both averaged for periods of 48 hours to several days of operation constant voltage

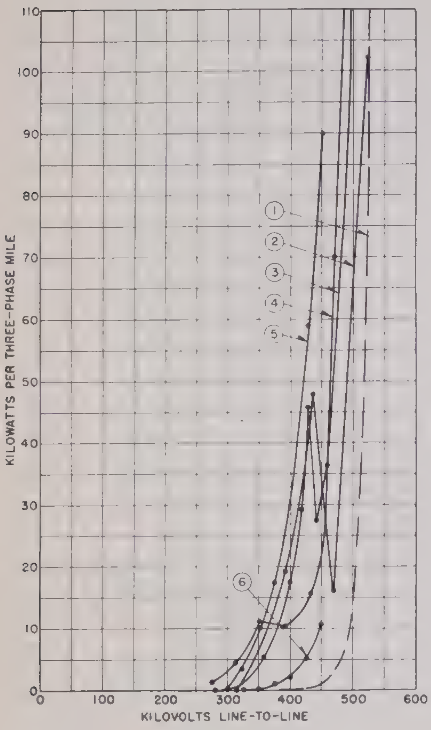

Figure 4. Three-phase corona loss under different weather conditions. Data for curves 5 and 6 were taken single-phase and have been converted to 3-phase based on surface gradients for 45 feet flat spacing

Curve 1—Mean of 20 fair-weather curves
Curve 2—Light rain; conductor spacing 45 feet
Curve 3—Light rain; conductor spacing 32 feet
Curve 4—Rain; conductor spacing 45 feet
Curve 5—Heavy fog, conductor surface wet; spacing 45 feet
Curve 6—Snow flurries; spacing 45 feet

is indicated in Figure 2 for 454 and 376 kv. In determining the time required for a conductor to stabilize, the 532-kv curve in Figure 2 may not be significant because the conductors have never been energized for long periods of time at this voltage.

The wide range of loss readings which are obtained at a given voltage on successive fair-weather voltage runs indicates that comparisons of conductors should not be based on single observations.

Of the weather factors causing high corona loss, rain, sleet, and snow are the most important. High corona loss has been recorded during fog, but it is believed that this condition was caused by condensation of moisture on the surface of the conductor which is not likely to occur on an operating line. Temperature, humidity, barometric pressure, and atmospheric voltage gradient have an effect which is small compared to that of rain. Figure 1, in which most of these factors are recorded, is a typical example of how they vary. Separation of weather factors requires detailed analysis of a large number of records because most of the time several of the weather factors change together.

Preliminary analysis shows a consistent correlation between corona loss and average rate of rainfall.[10] Remarkably smooth curves are obtained if the corona loss, averaged over periods of from 48 hours to several days of operation at constant voltage, is plotted against average rate of rainfall for the same period. This is shown in Figure 3 for line voltages of 398 and 454 kv. These curves are based on data taken under a variety of weather conditions and during different seasons. Except for a few points at high rates of rainfall, no attempt has been made to select rainy periods. Their remarkable consistency indicates that such curves might be an acceptable basis for estimating annual corona loss.

To illustrate further the effect of weather, Figure 4 shows curves of voltage versus corona loss taken with indicating instruments. Curve 1 gives the average loss for fair weather, and the other curves indicate the loss for foul weather. These curves illustrate the wide variation of corona loss which is present under different weather conditions.

More significant information is obtained from the graphic records of all-weather corona loss than from individual fair-weather voltage runs. From graphic records, the annual corona loss can be estimated and its economic importance determined. From an analysis of corona-loss graphic records and weather charts, examples of which are shown in Figure 1, curves of the type illustrated in Figure 5, which show the per cent of time that the loss exceeds values given by the ordinate, can be plotted. It will be observed that the fair-weather losses are small and that for periods of known rainfall the losses are high. "Fair weather" in this figure is a condition in which no

Table I. 3-Phase Corona Loss on Conductors at 390 Kv Phase-to-Phase

Line Conductor	Kw Per 3-Phase Mile Max.	20%*	50%†	Avg.	Test	C. Curve No.
Group 1—Nov. 29 to Dec. 29, 1948—2.82 Inches of Rain						
1.65″ HH	90	8.0	2.0	5.2	3-Phase	225–1
1.65″ ACSR	120	8.1	2.1	7.4	¶	227–1
2.0″ ACSR	50+††	3.3	1.7	3.4	3-Phase¶¶	226–1
2.0″ ACSR	111	3.0	1.8	4.1	¶	229–1
2×0.92″–20	131	22.5	2.3	8.1	**	228–1
Group 2—Dec. 29, 1948 to Jan. 25, 1949—1.5 Inches of Rain						
1.65″ HH	74	2.6	1.5	4.8	3-Phase¶¶	214–1
1.65″ ACSR	99	3.0	1.8	4.4	¶	215–1
2.0″ ACSR	90	2.6	1.5	2.9	¶	217–1
2.0″ ACSR	25	1.5	0.8	1.6	3-Phase¶¶	212
2×0.92″–20	96	3.0	1.8	5.6	**	216–1
Group 3—Jan. 25 to Mar. 1, 1949—1.7 Inches of Rain						
1.65″ HH	98	5.7	1.0	5.3	3-Phase¶¶	197–1
1.65″ ACSR	133	4.8	1.9	6.3	¶	218–1
2.0″ ACSR	117	3.0	1.8	3.9	¶	222–1
2.0″ ACSR	46	0.8	1.8	2.9	3-Phase¶¶	206–1
2×0.92″–20	132	6.0	1.8	7.8	**	197–1

* Values exceeded 20 per cent of time.
† Values exceeded 50 per cent of time.
¶ Outside phase of 3-phase line with different conductor.
** Middle phase of 3-phase line with different conductor.
†† Meters went off scale. This is an estimated value.
¶¶ Conductors have 45 feet horizontal spacing.
Values given for conductors tested under conditions marked ¶ and ** are three times the per-phase values obtained. This procedure theoretically yields low values when the outside phase is used and high values when the middle phase is used.

Table II. 3-Phase Corona Loss at 390 Kv Phase-to-Phase*
For Three Months: Nov. 29, 1948 to Mar. 1, 1949

Conductor	Kw Per 3-Phase Mile		
	Max.	20%†	Avg.
1.65″ HH-Cu	98	5.4	5.1
1.65″ ACSR	133	5.3	6.0
2–0.92″ I Core Cu	132	10.7**	7.2
2.0″ ACSR 3-Phase	50+††	1.7	2.6
2.0″ ACSR 1-Phase	117	1.7	3.6

* See Notes at bottom of Table I.
† Values exceeded 20 per cent of time.
** This value high because of data in Curve 228–1 Table I.
†† Estimated value—meters went off scale.

rain is indicated by a conventional graphic rain gauge. "Rain only" is a condition as observed by the test men during the day and operating personnel during the night, in addition to the records from the rain gauge. With the more sensitive photographic weather recorder which is now being used, the fair-weather curve will be lower. The relative periods of fair and rain conditions are reflected in the all-weather curve which is obtained by averaging the all-weather corona loss over the entire period.

Table I is a résumé of some of the data obtained from curves of all-weather losses for different conductors. The data were taken during the 3-month period from November 29, 1948 to March 1, 1949, with the lines energized at 390 kv phase-to-phase.

The average corona loss of different types of conductors depends not only on the applied voltage, but also on the relative duration of fair and foul weather. Table II, which summarizes the three months' data of Table I, shows how the information can be tabulated but does not contain information extending over sufficiently long periods to permit reliable comparison between conductors. The conductors were tested at other voltages during the periods indicated, but this table presents only the information obtained at 390 kv. Records of this nature have been continued and are still being made. Further reports concerning these records will be issued from time to time.

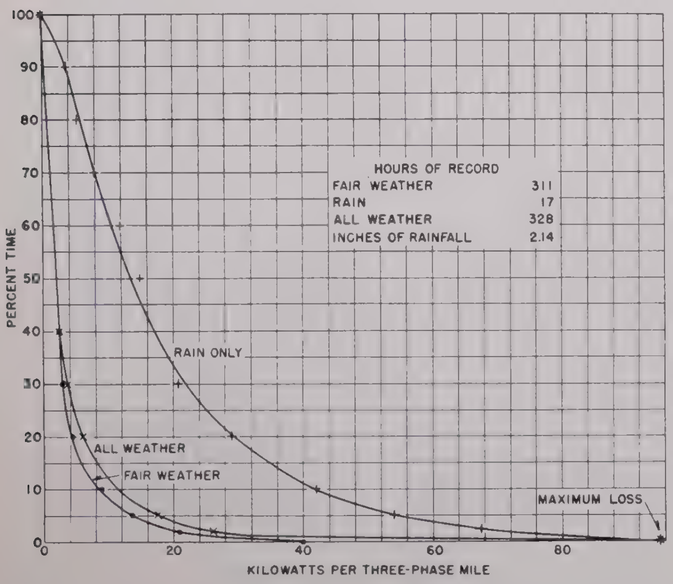

Figure 5. Corona loss record for one month on line 2 at 395 kv line-to-line during fair, rain, and all weather conditions. Ordinate indicates per cent time losses exceed the abscissa

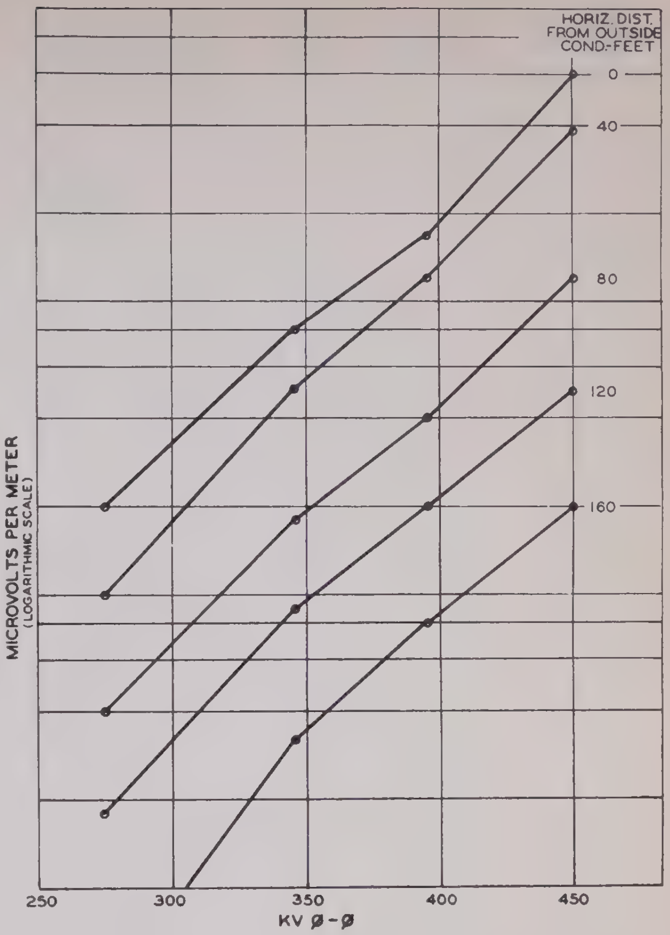

Figure 6. Radio influence variation with line voltage at distances of zero to 160 feet at right angles to line 1

The average values of corona loss, such as given in Table II, can be expected to be the same on operating lines as they are on the test lines. However, for lines of practical length the maximum value of corona loss will be much less than on test lines because extremes of weather are not likely to exist all along a line simultaneously. An evaluation of the weather conditions along any proposed right-of-way is necessary before an attempt to estimate the average and maximum values of corona loss can be made.[9]

When this investigation was started, the published information available on radio-influence characteristics of transmission lines was believed to be insufficient for the prediction of these characteristics for a line designed to operate at voltages appreciably higher than the voltages used at the present time. The most recent publications[9,10,13–15] present most of the information available and have been published since the Tidd project was planned and started. Because of the clearly indicated need for the consideration of radio influence in the design of extra-high-voltage lines, it was decided to undertake a major study of radio influence using the Tidd test lines. A laboratory test program is also in progress to co-ordinate laboratory and field data.

The radio-influence problem consists essentially of two

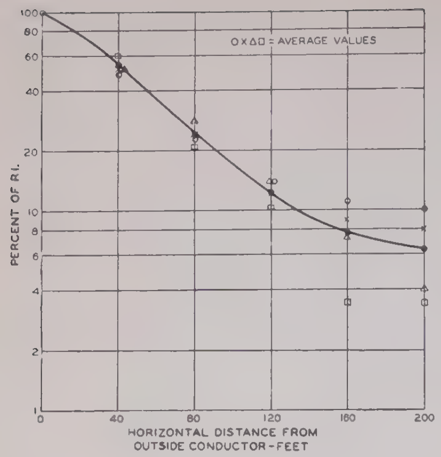

Figure 7. Attenuation of radio influence in per cent of values measured directly below outer phase conductor for line voltages from 138 to 450 kv phase-to-phase

parts: the determination of the radio-influence factors of transmission lines and the evaluation of these factors in terms of their effects on the communication services. One practical approach to the second part is the evaluation of data and experience on existing high-voltage lines as a bench mark.

It was planned to determine the effect of voltage and weather on radio influence for various conductor types, sizes, and spacings over long periods of time using graphic radio-influence meters so that average fair-weather and all-weather data would be available for analysis. Measurements have been made over the frequency range of 0.015 to 400 megacycles per second. Some of the data over this portion of the radio spectrum have consisted of manual readings, generally obtained during fair weather. Fair weather is considered to be any weather other than fog, rain, sleet, or snow environment around the conductors, and with conductor surfaces free of water, ice, or snow. Lateral and longitudinal profiles of radio influence have been made with the available portable meters. The effect of line voltage on radio influence has been investigated both with portable meters and with the graphic radio-influence meters.

The equipment for radio-influence measurements consists of standard radio noise and field intensity meters[16–18] and a trailer equipped with amplitude-modulated, frequency-modulated, and television receivers.

The variation in radio influence with weather is being recorded with graphic meters at several voltages and for two conductor sizes. A portion of chart record for each of two lines is shown in Figure 1. It can be seen from this figure that snow and rain increase radio influence. The relative values of radio influence for the short period of time shown in this chart are not necessarily the same as would be obtained over a long period. There are considerable variations in radio influence during fair weather, and the causes for these variations have not been completely determined.

The relative change in radio influence with line voltage for different horizontal distances from the outside conductor is shown in Figure 6. The rapid rise of radio influence with increase of line voltage is apparent, as is the drop with increase in horizontal distance from the conductor. The slope of radio-influence curve with voltage, for conductors of this size, is approximately the same as obtained by other investigators.[9,10]

Measurements of the lateral attenuation have been made at several frequencies with lines energized both single phase and three phase. Some of the data obtained are shown in Figure 7. These data are from 62 tests at voltages of 138 to 450 kv line-to-line. The small spread of the test points indicates that the lateral attenuation is practically independent of line voltage.

Measurements obtained under the center-phase wire at

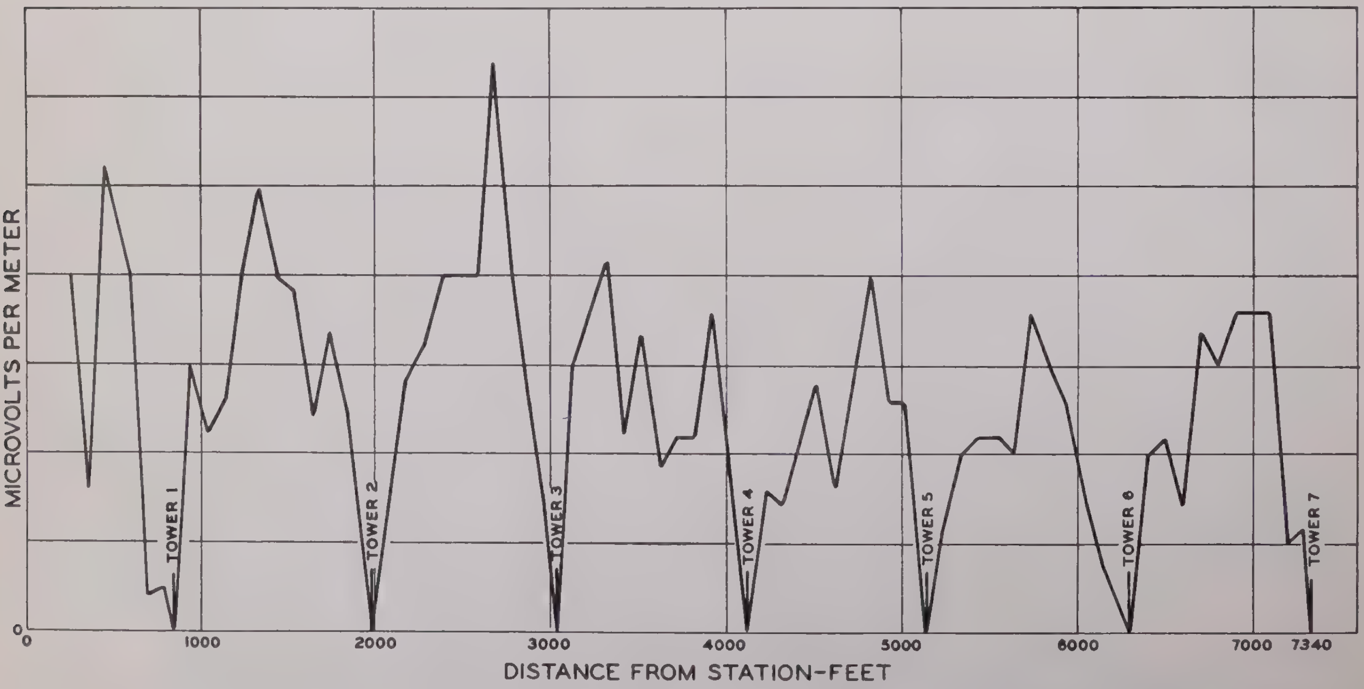

Figure 8. Radio influence profile measured along test line under middle-phase conductor. Line energized at 475 kv phase-to-phase

475 kv are shown in Figure 8. The variations of radio influence along the line are believed due to shielding by towers, change in conductor height, and reflections. The apparent attenuation is probably due to a change in radio influence during the three hours which were required for the test.

Measurements of radio influence over the frequency range show that radio-influence values vary inversely as the frequency. Tests with amplitude-modulated, frequency-modulated, and television receivers indicate that radio influence may affect amplitude-modulated broadcast reception without appreciably affecting frequency-modulated and television reception.

The evaluation of the effects on the communication services and tolerable limits of radio influence requires consideration of the characteristics of radio influence obtained and its effect on the various communication receivers, available signal intensities along the line, satisfactory signal-to-noise ratios, effects of weather, number, and type of receivers in vicinity of line, distances of receivers from the line, transfer of radio influence to lower voltage circuits, and means for improvement of reception at a particular receiver.[19,20]

It seems quite reasonable to permit higher levels of radio influence on extra-high-voltage transmission lines than on lower voltage lines for several significant reasons: the direct coupling to receiver antennas will generally be less; there will be only a few receivers near the line; there will be few parallels and cross-overs anywhere near the line.

While some test data still remain to be recorded, most of the information has been obtained. The large amount of work involved in analyzing and correlating these data still remains to be done.

A summary of the large amount of data which has been obtained at the field test location may be of interest. Up to January 1, 1950, over 12,000 feet of graphic records from corona loss and radio influence instruments have been obtained. Over 200 corona-loss-versus-voltage runs have been made, including 3-phase and single-phase tests. In addition, all-weather recording meters have been in almost continuous operation, but their results have not been included in the foregoing summary of graphic records of the tests.

By February 1950 only part of the data thus far obtained in the field had been analyzed and correlated. For this reason only typical data are presented in this article, and the conclusions drawn must be considered tentative. No definite conclusions can be drawn at this time, but they must await the more complete analysis of all significant data.

A series of complete reports giving detailed analyses of the data obtained on conductors tested and information on the application of these data to extra-high-voltage line design is planned for presentation before the AIEE in the near future.

TENTATIVE CONCLUSIONS

1. Voltage-corona runs are primarily of theoretical interest, and in general, are less significant for comparing conductors than voltage tests of long duration. The all-weather corona loss of conductors is believed to be of more significant value in studying the economic value of corona loss on a high-voltage line.

2. Corona loss is a function of the combined effect of surface and weather factors. New conductors generally produce more corona than is produced by conductors which are aged.

3. The ratio-influence problem involves the determination of radio-influence factors which are to be expected on a line of specific design and the proper evaluation of these factors in terms of their effects on communication services to be encountered. A great deal of work has been done on both phases of the problem, and serious consideration must be given to this feature in the design of extra-high-voltage lines.

4. While some definite values on corona loss and relative figures on radio influence are presented in this article, they must be considered tentative. A series of complete reports to be presented in the near future will give complete information both on corona loss and on radio influence, and application of these data to extra-high-voltage transmission line design.

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Measuring Dissipation and Dielectric Constants

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THE VARIATION of susceptance method of measuring dissipation factor has been described by Hartshorn and Ward.[1] This article describes apparatus and technique designed to increase the speed and, under certain conditions, the accuracy of this method by reducing the number of manual adjustments and instrument readings normally required in its application. A recording meter is employed to obtain traces of the resonance curves for the circuit with and without the dielectric specimen. This is done by having a constant-speed motor-driven capacitor tune the circuit through resonance while a recording milliammeter operated from the vacuum-tube voltmeter traces the voltage resonance curve. Limit switches operate relays which reverse the motor at each end of the travel of the micrometer tuning capacitor, so that the circuit is automatically tuned back and forth through resonance. During the test it is necessary to make only two readings, the settings of the specimen capacitor with and without the specimen in place and to make only one accurate manual capacitor setting for resonance. The resonance curves can be examined at leisure and the computations can readily be made from them. A permanent record of the test is obtained.

Figure 1 shows a cross-sectional view of the motor-driven capacitor assembly. The specimen capacitor *4* is a 2-inch diameter parallel-plate capacitor as recommended by the American Society for Testing Materials.[2] The upper electrode, which is the ungrounded one, is suspended from the grounded frame by four ceramic cylinders *8*. The lower, grounded electrode of the specimen capacitor is mounted on a piece of ceramic tubing *5*. The outside of this tube is painted with du Pont ceramic silver coating number 4545, and copper-plated. The brass electrode is soldered to the copper plating and the other end of the tube is soldered to an Invar tube *6*. This Invar tube is threaded with 40 threads per inch for a distance of $1^{1}/_{2}$ inches and threads through a hole in the grounded frame of the apparatus. "Oil dag" is used to lubricate the threads. A 3-inch-diameter disk *7* accurately divided around its circumference into 100 divisions is attached to the bottom of the Invar tube beneath the grounded frame of the apparatus so that changes in the spacing of the specimen capacitor may be accurately made.

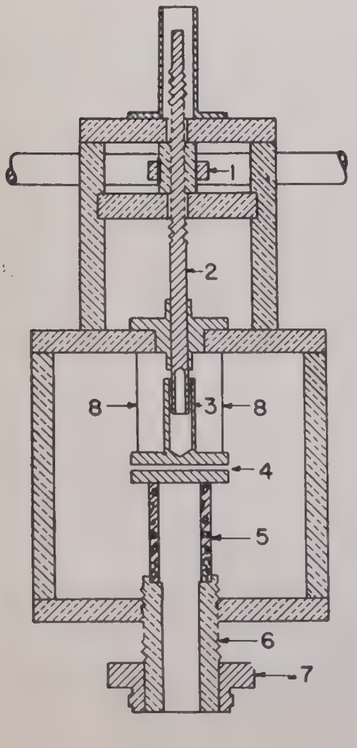

Figure 1. Sectional view of motor-driven micrometer capacitor assembly

Limit switches operate relays which reverse the motor at each end of the travel of the micrometer tuning capacitor, so that the circuit is automatically tuned back and forth through resonance until the motor is stopped

The known variable micrometer-capacitor is a cylindrical capacitor mounted directly above the specimen capacitor. The outer, ungrounded electrode *3* is $1^{1}/_{2}$ inches long and five-eighths of an inch in diameter and contains a hole 7/16 of an inch in diameter and $1^{9}/_{16}$ inches deep. The high-voltage electrodes of both the specimen and micrometer-capacitors are turned from a single piece of brass so as to eliminate the resistance and inductance of the leads between them. The lower $3^{1}/_{2}$ inches of the inner grounded electrode *2* is 3/8 of an inch in diameter, the remainder, except for the top one inch, is threaded with 5/16-40 threads. A 1/4-inch-diameter hole approximately one inch deep is drilled up through the bottom of the grounded electrode to eliminate capacitance between the bottom of the grounded electrode and the ungrounded electrode, thereby obtaining a more nearly linear relationship between the position of the ungrounded electrode and the capacitance of the micrometer-capacitor. A 1/8-horsepower 1,200-rpm motor drives the grounded electrode in or out of the high-voltage electrode at a rate of 1.6 seconds per revolution which gives a change in capacitance of 8.76 micromicrofarads per minute.

Five experimental runs were made at 24-hour intervals on each of 35 specimens. For all values of dielectric constant found, ranging from 3.0 to 7.3, the average deviation from the mean was always less than 0.1 and it was less than 0.05 in all but a few cases. The values of dissipation factor obtained by this method were quite good. Only in the case of glass were the percentage errors large, and here the average deviation was less than 0.005 in every case. In most cases the per-cent average deviation is about two-per cent or less, which is quite good for all but the most precise work.

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Prediction of Temperature Rise From Heat Run Data

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WHEN TEMPERATURE-TIME data from heat runs depart markedly from a simple exponential form, existing methods of predicting the ultimate rise from early data may be inaccurate. Previous methods for predicting the ultimate temperature rise of windings have assumed that the rise follows

$$\Theta = A(1-\epsilon^{-\alpha t}) \tag{1}$$

where

Θ = temperature rise, degrees centigrade
α = reciprocal of thermal time constant, minutes^{-1}
t = time, minutes
A = steady-state value of Θ, degrees centigrade

This is not accurate for apparatus in which there are several heat sources and separate heat-absorbing masses. On many devices such as electromagnets, temperature follows the 2-term equation

$$\Theta = A(1-\epsilon^{-\alpha t}) \pm B(1-\epsilon^{-\beta t}) \tag{2}$$

wherein β and B are analogous to α and A. In such cases, early heat-run data may be extrapolated to find the steady-state rise by using the method described in the following paragraphs.

By differentiating equation 2, the sum of two exponentials is obtained

$$\frac{d\Theta}{dt} = A\alpha\epsilon^{-\alpha t} \pm B\beta\epsilon^{-\beta t} \tag{3}$$

Each of these terms plots as a straight line on semilog paper. Thus, if experimental values of $d\Theta/dt$, taken from early heat run data, are plotted against time as in Figure 1, it is possible to find, by trial, two lines, A and B, whose ordinate scale values combine to give a curve which fits the data (curve C). In this case, the ordinates add; in other cases, when the iron of the device tends to heat the coil, they must be subtracted in order to fit the data. The trend of the data always indicates which process is required for the proper prediction of temperature rise.

Finding α and β from the slopes of lines A and B respectively, the ultimate rise, Θ_u, is predicted from

$$\Theta_u = \Theta_t' + \frac{\Upsilon_a'}{\alpha} \pm \frac{\Upsilon_b'}{\beta} \tag{4}$$

where

Θ_t' = value of Θ when prediction is undertaken
Υ_a', Υ_b' = ordinate scale values of lines A and B, respectively, at this same time, degrees centigrade per minute

In most cases, Υ_b reaches negligible values early in the run, so line A is simply the asymptote of the data points.

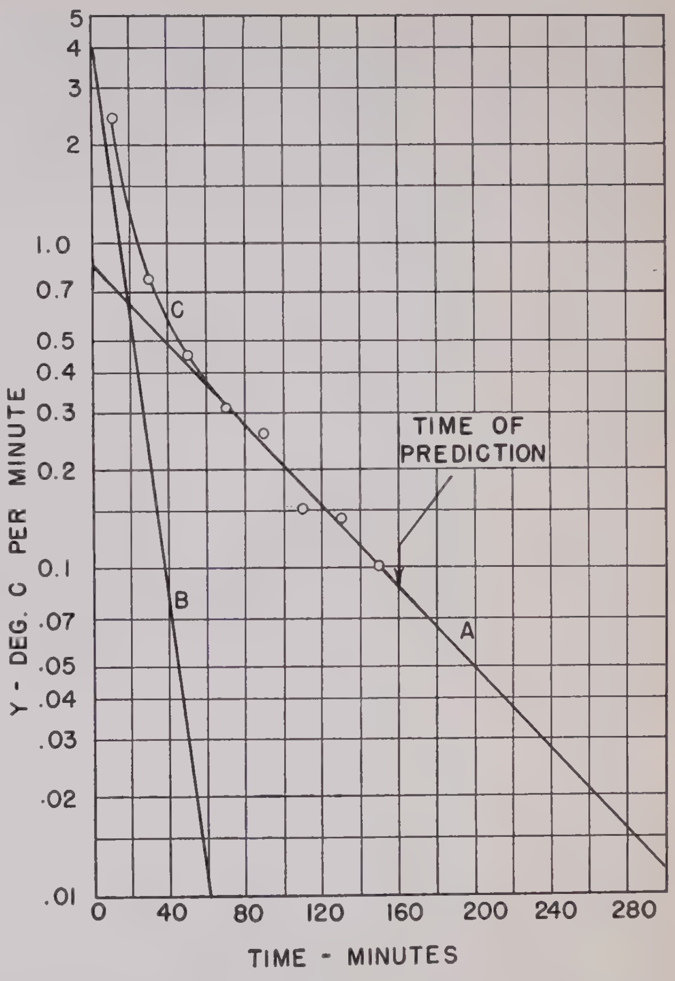

Figure 1. Rate-of-rise curves of a large d-c magnet

In any case, great accuracy is not required in locating lines A and B. For example, an error of ten per cent in slope will cause about the same per cent error in the estimate of the remaining rise, but if the rise at the estimate time is already 80 per cent of the ultimate, this will result in only 2-per cent error in the final figure.

If the predicted rise is not the one desired, a readjustment of the voltage (or current) is made, causing the temperature to approach a new equilibrium. The $d\Theta/dt$ versus t plot is continued without interruption. It will deviate from its original locus, but will still be of the form of equation 3; hence, the new Θ_u may be estimated in the regular manner, confining the determination of component lines to the period after readjustment.

The method described is applicable to devices of all sizes but is most useful for large slow heating ones where the possible time saving justifies the calculations. This saving is frequently more than 50 per cent of the time otherwise required.

Digest of paper **49-244**, "Prediction of Ultimate Temperature Rise From Early Heat Run Data," recommended by the AIEE Committee on Industrial Control and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cincinnati, Ohio, October 17–21, 1949. Published in AIEE *Transactions*, volume 68, 1949, part 2, pages 1164–6.

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A New Device for Calibrating Watt-hour Meters

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A NEW device has been developed to provide a better means of calibrating watt-hour meters, particularly in the field. With this device, the field testing of watt-hour meters is made much faster and easier as compared to the conventional methods of counting and timing of disk revolutions because an instantaneous and continuous visual indication of meter accuracy is obtained. In general, closer adjustment to correct registration is obtained than by the methods involving successive trials. The device is portable. No special disks, disk markings, or the like are required.

Other methods, such as the stroboscopic methods and automatic counting of revolutions, have been developed for laboratory or shop use and have some of the same advantages. However, these methods are not applicable to field testing because they require that the meters be mounted in a special stand, or jig, and, furthermore, the equipment is too elaborate and cumbersome.

The new device compares the speed of the disk of the meter under test with that of a standard watt-hour meter by photoelectric means. An instantaneous and continuous comparison of speeds is indicated on the screen of a cathode-ray tube.

Both the standard and the test watt-hour meters are equipped with a light source, a system of lenses and mirrors, and a photoelectric cell. This test unit is shown in Figure 1. It is permanently mounted on the standard and temporarily mounted on the meter under test. Serrations on the disk of each meter interrupt the light on the photoelectric cells as the disks rotate. Serrated disks are standard on all modern watt-hour meters. Figure 2 shows how the variation of current in the photoelectric cell on the standard meter is utilized to control the horizontal-sweep circuit of a cathode-ray tube, and on the test meter to produce a vertical deflection on the screen. The resulting trace is stationary when the disks of both meters are rotating at the same speed, and moves across the screen when the two speeds differ. The direction of travel determines whether the meter under test is fast or slow. It is not essential that the disk speeds be the same as long as the frequencies of the periodic currents from the photoelectric cells attached to the meters are integral multiples, one of the other. This permits the use of the same standard meter to calibrate meters having different numbers of disk teeth and different disk constants. The action of the trace is used to obtain check on the meter as it is found by varying the voltage on the standard, by means of a tapped autotransformer with suitable vernier adjustment, to match its speed to that of the meter under test. It is also used to obtain correct registration of the meter under test by resetting the standard for the desired registration and by changing the adjustments of the meter under test to match its speed to that of the standard.

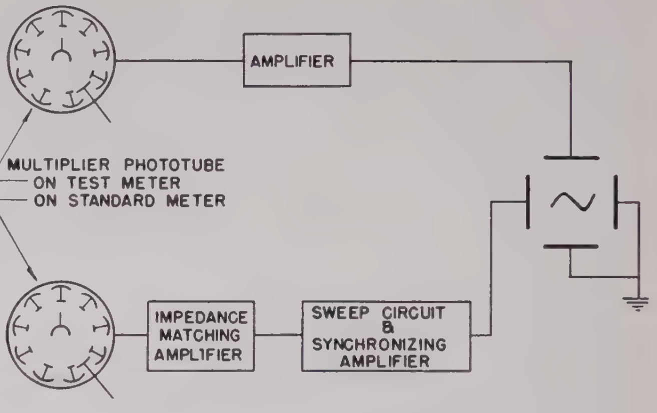
AMPLIFIER
MULTIPLIER PHOTOTUBE
ON TEST METER
ON STANDARD METER
IMPEDANCE MATCHING AMPLIFIER
SWEEP CIRCUIT & SYNCHRONIZING AMPLIFIER

Figure 2. Block diagram of the electronic circuit showing the control of the horizontal sweep circuit by the phototube of the standard meter and the vertical deflection produced by the phototube of the test meter

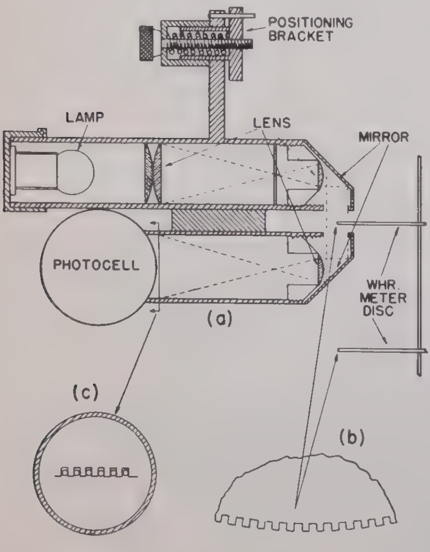

Figure 1. Test unit

A—Optical system and photoelectric cell
B—Section of watt-hour meter disk
C—Section of photoelectric cell light shield

The new device has been used for calibrating station watt-hour meters for a period of about eight months. It has been found that accurate calibration by this method requires only one-third as much time as the conventional method of counting disk revolutions. The device detects erratic disk motion such as caused by defective bearings and registers or by foreign material on the disks or magnets, much more readily than the conventional method. The tester can observe the action of the trace on the cathode-ray screen over long periods of time with no eye strain.

The sensitivity of the detecting device is such that meters can be calibrated with an accuracy of 0.1 per cent.

Digest of paper **50-116,** "A New Device for Calibrating Watt-hour Meters," recommended by the AIEE Committee on Instruments and Measurements and approved by the AIEE Technical Program Committee for presentation at the AIEE North Eastern District Meeting, Providence, R. I., April 26–28, 1950. Scheduled for publication in AIEE *Transactions,* volume 69, 1950.

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Primary Batteries

CHARLES H. CLARK

Lightweight power supplies and batteries have become increasingly important for military and commercial use since the beginning of World War II. This article describes several of the developments made in the past few years with respect to military primary batteries.

DR. G. W. VINAL'S article,[1] delivered to the AIEE in 1947, was a fine historical presentation, bringing the status of the dry-cell battery up to the beginning of the postwar era of World War II. Whereas it did, among other things, indicate that unusual impetus had been imparted to the dry-cell industry as a result of the war, it did not cover in too much detail the specific improvements that have been brought about by gains in recent technology. The purpose of this article is to discuss, in general, some of the highlights underlying this unusual interest in dry batteries and to discuss some of the important phases of work which are in progress at the present time. In the history of mankind there has been no more impetus placed on lightweight power supplies and batteries than has existed in World War II and the postwar era. This has been largely brought about by the unusual advance in electronics, both from the military and commercial points of view, and the realization that the trend in miniaturization in some types of electronic equipments has brought about the need for small, compact, high-efficiency power supplies to which the dry-cell battery is unusually well adapted, provided certain improvements can be incorporated.

The military services, with their unusually stringent demands for quality performance, under world-wide operating conditions and wide diversification of application, are inherently interested in the advance of an art that has existed for nearly a hundred years.

Not many people realize the enormous advances that have been brought about in military and commercial dry batteries through the combined efforts of the military and commercial development organizations. In order to arrive at some understanding of the progress that has developed, this article will include a general discussion of three types of dry-cell battery systems in which the military services have been interested and are actively conducting research and development work within the Signal Corps Engineering Laboratories and throughout the dry battery industry, universities, and other research and development organizations.

LECLANCHE SYSTEM

THE LECLANCHE system to be considered herein is a term loosely applied to the zinc, ammonium-chloride, and manganese-dioxide cell. This battery was the only type of dry-cell battery used by the military services for a great many years because it was the only one that was completely developed for large production and for which nation-wide facilities were available. Prior to, and at the beginning of World War II, this battery was a commercial grade product which did not meet the requirements set up by world-wide military use. There were many things to consider in the use of such a product, especially in the quantities that were normally demanded. Some of these considerations involved the use of critical materials from the natural resources point of view, operational characteristics from subzero temperatures to somewhat in excess of normal temperatures, and ease of storage throughout a world-wide supply system. These requirements are not normally reflected in commercial usage where supply systems are set up for rapid consumption and for operation at temperature conditions which do not deviate excessively from that which is considered a normal temperature.

The greatest amount of progress accomplished in the over-all improvements of the Leclanche system has been the result of careful studies of the constituent materials and processes used to make a dry battery. Accordingly, several of these phases will be discussed herein.

During World War II, military dry batteries were required to operate at subzero temperatures. The conventional dry cell, however, gave only approximately 15 per cent of its normal 70-degree Fahrenheit capacity at 0 degrees Fahrenheit, 2 to 5 per cent of its 70-degree Fahrenheit capacity at −20 degrees Fahrenheit, and 0 per cent of its 70-degree Fahrenheit capacity at −40 degrees Fahrenheit. As a result of numerous internal changes and improved constructional techniques, dry batteries were produced which gave 10 to 20 per cent of their 70-degree Fahrenheit capacity at −40 degrees Fahrenheit. Later the limit of operation was extended by military requirements to −65 degrees Fahrenheit but, unfortunately, these earlier low-temperature batteries were inoperative at −65 degrees Fahrenheit.

A considerable amount of research and development, therefore, has been put into the development of a dry battery capable of operation at −65 degrees Fahrenheit. This has included the study of: the characteristics of various electrolytic systems at temperatures as low as −100 degrees Fahrenheit; the characteristics of various electrochemical systems at temperatures as low as −100 degrees Fahrenheit; and the fabrication of sample dry cells that would operate at −65 degrees Fahrenheit. To date, cylindrical dry cells have been constructed which give at −65 degrees Fahrenheit approximately 10 to 15 per cent of their 70-degree Fahrenheit capacity. Considerably more work is under-

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This is the first of three articles on batteries. The other two articles will appear in future issues of *Electrical Engineering*.

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way in an attempt to improve these low-temperature capacities and also the ability of the low-temperature cells to maintain their capacity after storage periods of at least one year at 70 degrees Fahrenheit.

It was quite evident in the early days of the war in the Pacific that equipment (batteries included) did not stand up under the high-temperature and high-humidity conditions encountered. As the war progressed, this problem was alleviated to some extent by improved packaging methods and materials. Specific developments on dry batteries alone have resulted in their withstanding storage for 12 months at temperatures as high as 113 degrees Fahrenheit. Attempts are being made to improve them so that they can satisfactorily withstand storage at temperatures up to +160 degrees Fahrenheit. This is being done by studies of internal construction, fabrication techniques, sealing materials, and packaging materials.

Probably the most important single constituent responsible for dry battery capacity is manganese dioxide. Unfortunately, all types of manganese dioxide do not function properly in dry cells. The only natural-grade manganese dioxide that can be presently used in military-grade dry batteries comes from the African Gold Coast. This, of course, creates a serious supply problem in the event of an emergency. Domestic as well as foreign sources are being canvassed for this purpose and samples of natural ore from all over the world have been submitted to the Signal Corps Engineering Laboratories for evaluation. Another method of obtaining a supply of manganese dioxide for military batteries is by preparing it by synthetic methods, using low-grade domestic ores.

Although many methods of fabricating synthetic manganese dioxide are known, the resultant materials do not all possess the desired dry-battery characteristics. It has been found that γ-phase manganese dioxide gives the highest capacity dry cells (cells made with pure γ-phase manganese dioxide give almost double the capacity of cells made with natural African ore). This material is made by the electrolysis of acid manganous sulfate solution, with proper control being maintained over critical process variables. Good synthetic manganese dioxide is presently being made by two dry-battery manufacturers, but the quantities produced are by no means large enough to support the entire battery industry. Plans are under way for the establishment of a large-scale producer of this material.

Carbon black is the material that is added to manganese dioxide in the dry-cell cathode to make it conductive. Like manganese dioxide, its crystalline characteristics are very important in so far as dry-cell operation is concerned. The only carbon black that was hitherto acceptable for use in military-grade dry batteries was made in Canada. As the result of a large-scale experimental program with several domestic producers of carbon black, domestic blacks have been developed which test results indicate may be considered as satisfactory substitutes for the Canadian material.

Under normal operating conditions, the average dry cell only delivers approximately 40 per cent of its theoretical capacity based on depolarizing material available. Naturally it would be to the advantage of the equipment user if a better realization of the theoretical capacity could be obtained. Through the use of electrolytic manganese dioxide of the desired crystalline quality and improved fabrication techniques, it has become possible to attain practically 85 to 90 per cent of the theoretical capacity. The Signal Corps is of the opinion that the use of these improved techniques and component materials can be applied to all military batteries, resulting in a subsequent increase in capacity for all military dry-battery types. Several of the battery manufacturers, utilizing these new features for the production of military batteries, have improved capacities by as much as 50 per cent. They have also utilized many of these techniques in the improvement of their commercial batteries.

Many military equipments require power supplies considerably smaller than those presently available in standard Leclanche construction. In order to meet these requirements, developments are underway to produce these miniature batteries by using all of the information that has been derived from all of the investigations and developments previously mentioned. The aim is to obtain miniature cells which will operate at both low and high temperatures, store at high temperatures, and have high capacities per unit of weight and volume. Practically all of the larger dry-battery manufacturers are engaged in this type of development.

ALKALINE DRY BATTERIES

The alkaline dry battery (*R-M* system) was invented by S. Ruben in 1942. It is a zinc, potassium-hydroxide, mercuric-oxide system. Its advantageous operating characteristics for military-battery applications were readily observed and, for that reason, its development has become very important to the Signal Corps program. Whereas the alkaline dry battery's theoretical capacity per gram of cathodic material is lower than that of the Leclanche cell, its more compact construction and higher operating efficiency give it a much higher ampere-hour capacity per unit of weight and volume than the Leclanche system. These features have been described in considerable detail by Ruben[2] and Friedman and MacCauley.[3] Since the development of the *R-M* cell has resulted primarily from Signal Corps interest, most of the present-day developments are being performed with Signal Corps cognizance.

As a result of the rapid rate at which the *R-M* cell industry had to expand in order to meet production schedules during World War II, many production problems arose that resulted in batteries becoming defective after long periods of storage. Accordingly, efforts are being made today to improve the reliability of the *R-M* cell. This is being done by a very careful investigation of each of the cell components and battery-assembly techniques. Present indications are that the proper solutions are being found and that the future *R-M* cell will exhibit the desirable characteristics that have been predicted for it.

Although the *R-M* cell has always shown excellent room-temperature capacity, in its present structure it is not a good low-temperature cell. At 0 degrees Fahrenheit, it gives only about 2 per cent of its 70-degree Fahrenheit capacity and at −20 degrees Fahrenheit it gives 0 per cent of its 70-degree Fahrenheit capacity. It would naturally be advantageous to obtain the benefits of *R-M* operation at subzero temperatures and for that reason a considerable amount of research and development is being done along these lines. Thus far, an *R-M* cell has been developed which will operate at −65 degrees Fahrenheit. However, this cell is larger than a standard *R-M* cell having equivalent capacities at 70 degrees Fahrenheit. Attempts are being made to reduce the size of this low-temperature *R-M* cell.

As with the Leclanche system, it would be advantageous to have a miniature cell capable of operating satisfactorily at −65 degrees Fahrenheit and delivering these capacities at relatively high-current densities. Accordingly, investigations are under way to attain these desired characteristics by studying the effect of high-current-density discharge upon each of the alkaline cell components. Some promising results have been obtained to date, at least from a normal-temperature initial-capacity standpoint. In fact, it appears at this time as though this system offers the best promise for reducing battery size.

The development of an alkaline cell with an all-plastic case that is hermetically sealed has been under investigation for some time. Numerous plastics have been used, several of which appear promising. From preliminary models, there are indications that the plastic-case cell will have the same electrical characteristics as regular *R-M* cells but will be much easier and cheaper to fabricate. This should also eliminate electrolyte leakage problems.

MAGNESIUM BATTERIES

At the conclusion of World War II, surveys made of critical materials indicated that the supply of zinc was not sufficient to meet the exigencies of another such emergency. Hence, it was obvious that an investigation to find a suitable substitute for zinc in primary batteries should be made. Of the numerous metals in existence, a careful survey and study indicated that magnesium would probably offer the greatest chance of success along these lines. It must be kept in mind that the original objective was to substitute magnesium for zinc in the regular Leclanche battery, and to obtain comparable capacity and shelf life. It was originally believed that considerable trouble would be encountered in trying to obtain magnesium batteries that would meet a one-year shelf life requirement. However, a very well organized program resulted in greater than expected progress.

After an intensive screening program, magnesium alloy and electrolyte combinations were selected which gave indications of having dry-cell possibilities. Dry cells subsequently were made which have not only been equal to the standard Leclanche cell at normal temperatures on initial capacity tests, but also have been considerably superior. At room temperature, magnesium dry cells have delivered watt-hour capacities at least double those of zinc cells under standard Signal Corps tests. Delayed-capacity tests have indicated that the best formulation magnesium dry cells will deliver at least 90 per cent of their initial capacities after a one-year storage period at 70 degrees Fahrenheit. These cells, after being stored at 113 degrees Fahrenheit (50 per cent relative humidity) for three months, delivered about 90 per cent of their initial capacity. At −40 degrees Fahrenheit these magnesium cells give on initial discharge approximately 5 per cent of their 70-degree Fahrenheit capacities under low to medium discharge rates.

Since this is such a recent development, it is only natural that a great deal of experimentation and investigation remains to be done before the maximum benefits of the cell are to be realized. Although considerable capacity improvements have been obtained as a result of using the best formulation magnesium cells, 100-per-cent cathodic efficiency with these formulations has not as yet been reached. Every effort is being made to obtain the maximum efficiency from the cell.

As has been previously mentioned, the present design magnesium dry cell does deliver approximately 5 per cent of its 70-degree Fahrenheit capacity at −40 degrees Fahrenheit under low-drain applications. However, at higher rates, the cells will not operate at −40 degrees Fahrenheit. It is naturally very desirable for military purposes that the magnesium cell should operate satisfactorily at temperatures as low as −65 degrees Fahrenheit. In order that the magnesium cell will be able completely to replace the zinc cell for military applications, it is essential that low-temperature anodic, cathodic, and electrolyte formulations should be investigated.

In the present cell, a magnesium-hydroxide film forms on the magnesium anode, and, as a result of this, instantaneous voltage is not obtained immediately upon closing the circuit. A delay period, called "delayed action," of about one to five seconds is experienced before maximum voltage is attained. Whereas this may be acceptable in some cases, the delayed-action period cannot be tolerated in many military applications. In order to have the magnesium cell completely replace the zinc cell, this delayed-action period must be reduced. It is believed that this can be done by additional investigations of anodic and inhibitor compositions.

Attempts are now under way to have magnesium dry cells fabricated on a commercial scale by the dry-battery manufacturers. It is expected that the present design magnesium dry cells can be adapted to large-scale production using the existing facilities of the dry cell manufacturers, with only slight modifications of these facilities necessary for the change-over.

CONCLUSIONS

Under the sponsorship and guidance of the Signal Corps Engineering Laboratories, Fort Monmouth, N. J., a long-range research and development program is under way for the purpose of improving the operating characteristics of primary batteries over a temperature range of −65 degrees Fahrenheit to +160 degrees Fahrenheit.

Leclanche batteries have been improved considerably so that now they give increased capacities over the temperature range of −65 degrees Fahrenheit to 70 degrees Fahrenheit and are able to withstand storage under tropical conditions for reasonable periods.

The alkaline dry battery is being improved to that point where it has become more reliable after long storage periods. The low temperature characteristics of this system have also been improved to that point where operation at −65 degrees Fahrenheit is now possible.

Reducing the size of both of these battery systems is of critical importance as a result of the recent trend in military equipment designs. Investigations pertaining to this matter are under way, with considerable promise being shown by some designs.

Magnesium dry cells have been developed that give capacities at least double those of corresponding size zinc cells under the same test conditions. These cells have retained at least 90 per cent of their initial capacities after storage at 70 degrees Fahrenheit for one year. The cells do operate at −40 degrees Fahrenheit but only under conditions requiring low drain on the cells.

Although tremendous gains in each of the three previously mentioned cell systems have resulted from battery research and developments made during the past few years, continued research and development on each of these three cell systems is under way under the supervision and cognizance of the Signal Corps Engineering Laboratories in line with their policy of providing the military services with the highest possible quality power supplies.

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Electronic Excitation of Generators

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THE ROTATING COMMUTATOR and brush combination, to say nothing of the other components which go to make up an exciter system, are known to be the most vulnerable part of a generator. It could never be called upon to run long, continuous periods of time without shutdowns for servicing. Therefore, in considering the designs for any improvement it was intended that it would be possible to service vulnerable parts without shutdowns or without affecting the generator output; and at the same time it was desired to supply all spare exciter capacity necessary. It was believed that the exciter and regulator performance could be improved by the use of electronic components, which had already proved themselves over long periods of time in other industrial applications.

As a result of investigation it was found that the frequency of exciter troubles, as well as the uncertainty of maintenance requirements, were due principally to the following causes:

1. Variation in brush structure and composition, even with so-called identical style brushes, and sometimes with brushes from the same batch.
2. The influence of variation of current density on commutator performance.
3. Copper structure variation which led to commutator irregularities resulting in high bar and thermal instability.
4. Commutator bar slippage as affected by unusually high vibration causing brush skip due to high mica or commutator bar.
5. Commutator wear which required shutdown for proper correction.
6. Humidity variations.
7. Dust and dirt effect on brush wear and commutator cutting.
8. Banding failures due to overloading or mechanical failure.
9. Commutator riser failures.
10. Generator-field circuit-breaker failures due to contact corrosion when not operating over long periods of time.
11. Difficulties with parallel operation of exciters on a common-bus excitation system.

Although it was realized that steps have been taken to improve brush-type commutator machines, maintenance still cannot be accomplished completely while the unit is in operation. Therefore, it was felt that the electronic exciter offered the best possibility of eliminating most of the difficulties experienced. Some of the other features considered favorable to the electronic exciter are the following items:

1. Simplicity of the exciter alternator, its winding and installation, as compared to a d-c generator winding. Also the inherently smaller rotor and the total absence of banding, brush rig, risers, and commutator.
2. Electronic exciters could be a combination of all time-tried equipment; that is, the alternator and the ignitron.
3. The complete freedom from system disturbances as would not be the case with separate excitation furnished by motor-generator sets.
4. No spare excitation required.
5. Elimination of field circuit breakers and bussing with their inherent hazards.
6. Elimination of exciter-paralleling problems.

Essentially full text of paper **50-51**, "Excitation Improvement—Electronic Excitation and Regulation of Electric Generators as Compared to Conventional Methods," recommended by the AIEE Committee on Power Generation and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 30–February 3, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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PERMANENT-MAGNET PILOT EXCITER

The first step taken in eliminating exciter troubles was to improve the pilot exciter. Since the pilot's size and position at the end of the shaft caused it to be less stable than the main exciter, it was decided to use a 4-pole permanent-magnet rotor and 3-phase stator to deliver 120-cycle power to a stationary dry-type or electronic rectifier. A unit of this type was manufactured and placed on test for a period of eight months. It was subjected to all known hazards of short circuits and load variations and was found to be a very stable machine. Another unit was manufactured to be mounted on a 40,000-kw unit at the Seward Station of the Pennsylvania Electric Company. This unit went into service in August 1947.

In order to service the exciter of a generator without shutting down the entire system or affecting the output of the generator, an electronic exciter has been devised to replace the conventional rotating commutator and brush combination. In addition to the operation of test models, units of this type have been in regular service for more than two years and have proved entirely satisfactory.

During a scheduled shutdown for inspection and maintenance of the turbine approximately 15 months after the unit was put in service, a complete change of rectifier tubes was made, but no tube replacements had to be made before then. Several tubes had loose bases, but this condition no longer occurs in the tubes now being produced. During the initial operation of the unit it was apparent that tube life could be extended by preheating the filaments, so equipment providing automatic change-over to the station power supply was ordered, and the installation was made after the original unit had been in operation 15 months. In addition to prolonging tube life, the change-over to the separate power source provided field current for a longer period during shutdown of the generator, as well as supplying an emergency power source for the rectifier. It is simpler and more reliable than a hand-operated circuit breaker or a time-delay circuit in the anode supply of the rectifier.

Since it was recognized that the pilot exciter was responsible for a large number of unscheduled shutdowns, temporary action was taken on several machines by the Pennsylvania Electric Company as well as other utilities waiting for information on the new magnetic pilot. They used a storage battery in place of the pilot-exciter source and provided shaft extension for the application of the permanent-magnet pilot at a later date.

WARREN STATION EQUIPMENT

When the excitation for the two 37,500-kva turbine-generator units for the new Warren Station was under consideration in 1944 it was felt advisable to review the possibility of a complete elimination of commutator-type exciters from the shaft of these two units. Also, the possible elimination of all rotating-commutation d-c machinery in this plant was the general keynote. The final result is that the only equipment of the rotating-commutator type installed in this plant is a few small reversible positioning and valve-operating motors.

It was also felt that the electronic exciter, in addition to the features previously cited, would be superior in its response and ability to take overloads, as full electronic excitation provides the only ideal medium for the application of electronic regulation, which was also to be a part of this excitation system. In contrast to the brush-type commutation, the electronic type would have a much wider operating range, for the electronic exciter can operate at very light loads or severe overloads for long periods of time without damage. If parallel operation was ever required, it could be accomplished with simplicity and without the danger of feedback.

At the time the original electronic excitation system was proposed, the permanent-magnet pilot was to be an integral part of the system as shown in Figure 3. However, when the Warren Plant units were laid out as shown in Figure 1 it was not included because of the lack of actual field experience. It was finally conceded superior in many ways as is stated in a paper by A. P. Colaiaco, A. A. Johnson, and J. E. Reilly.[1] They pointed out that it would provide an

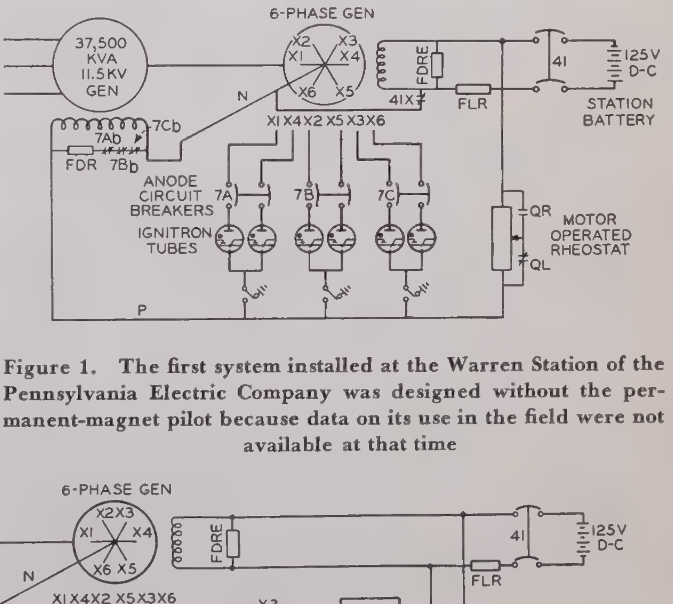

Figure 1. The first system installed at the Warren Station of the Pennsylvania Electric Company was designed without the permanent-magnet pilot because data on its use in the field were not available at that time

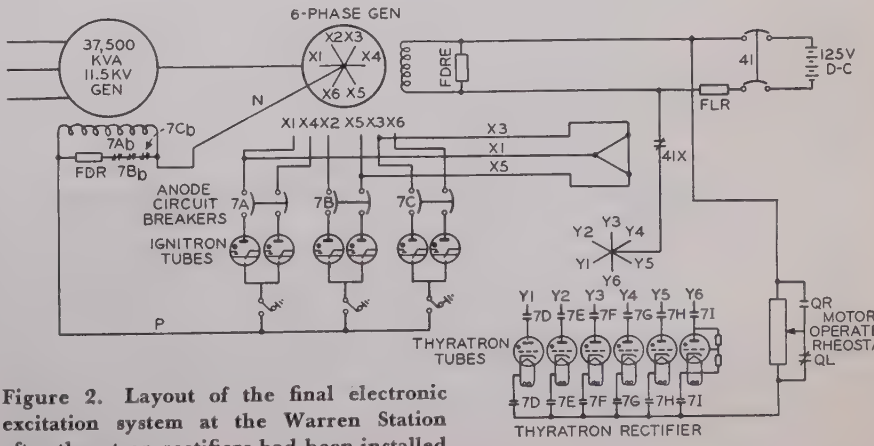

Figure 2. Layout of the final electronic excitation system at the Warren Station after thyratron rectifiers had been installed

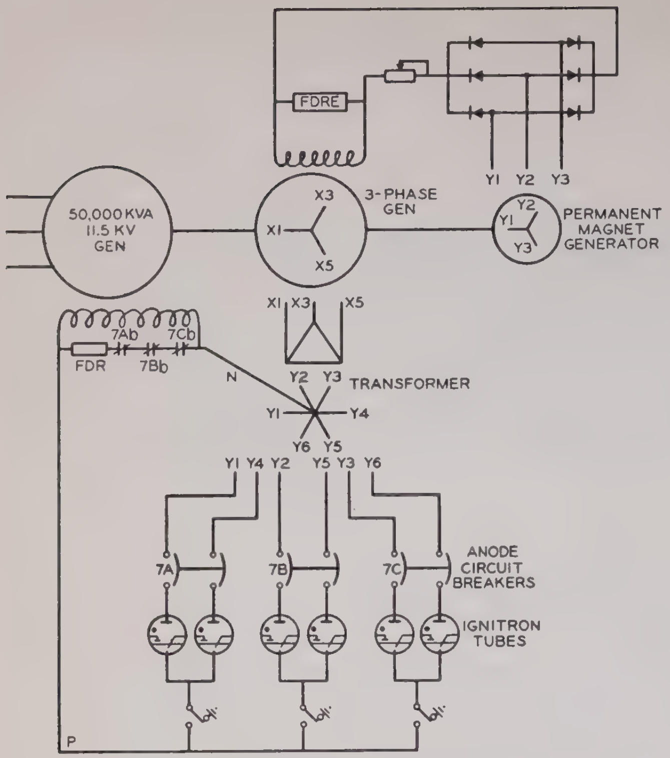

Figure 3. Design of the electronic exciter for a 50,000-kva unit for the Seward Station of the Pennsylvania Electric Company; the permanent-magnet-type 3-phase pilot produces a fixed field on the exciter alternator through a selenium rectifier

entirely separate low-voltage excitation unit for the main exciter. It is being used in the new generator being made ready for service at Seward Station of Pennsylvania Electric Company.

With the possibility of realizing complete electronic excitation for the Warren generators, engineers worked closely with manufacturers on all details. Several small defects were discovered and remedied when the Number 1 machine was put in service. The difficulties experienced were all of minor consequence and were to be expected in the initial product. The time required to correct them was lengthened by the fact that the main generator had to be up to full speed before any adjustments or checking could be done on any exciter units. In the newer unit for the Seward Station, a separate 3-phase supply from the station service can be used for checking before the turbogenerator unit is ready for service. Although it is a rather remote possibility, a failure of the exciter alternator would not be too serious since the electronic rectifier can be supplied from any 3-phase source.

It is of interest to note that a gaseous ignitron tube was discovered during the first week of operation of the Number 1 generator at Warren Plant. This condition was not previously detected because the tubes were not check-tested after shipment. This tube section was isolated immediately, and the tube was replaced while the generator was operating under full load. Because the rectification was removed from the shaft, no shutdowns were required in the following $1^1/_2$ years of operation. Contrasted with this, during the same period a similar generator, with brush-type commutation direct-connected exciter, had to be shut down completely to make necessary repairs to a high bar on its commutator. There were, however, during the $1^1/_2$-year period three arc backs registered, but they were cleared automatically and reclosed with no disturbances to the generator or the system.

Although some additional cost was expected on this type of excitation system over the cost of a conventional commutator-exciter system, the actual difference in over-all plant costs amounted to very little. The separate excitation is inherently built into each electronic unit; and the anode circuit breakers, which can be operated at will, completely supplant the conventional field circuit breakers. Other items not required are the field rheostat, high-speed contactors, field cubicle, busses, supply circuit breaker for a spare exciter set, spare exciter, conduit, and cables. For comparison, considering a similar 2-generator station equipped with two 40,000-kva units, the cost of the miscellaneous equipment necessary for conventional excitation, including a spare exciter, shows less than 10-per cent difference in over-all exciter cost.

The electronic exciter for the new 50,000-kva unit at Seward Station is being installed as shown in Figure 3. In this arrangement the permanent-magnet-type 3-phase pilot is to produce essentially a fixed field on the exciter alternator and through a selenium rectifier rather than the electronic rectifier. The change to the selenium rectifier was felt advisable because of its excellent record in similar low-power applications, and it is thought it will eliminate some tube troubles.

The shaft-driven exciter alternator in this case is a standard 3-phase unit which supplies power to the rectifier unit through a 3-phase to 6-phase transformer. This arrangement follows the use of standard equipment rather than a special 6-phase alternator as used in the Warren Plant units. At the same time it introduces additional flexibility. This arrangement would permit supplying the rectifier transformer from the station service bus for prechecking, preheating, and so forth. In the event of emergency or failure of the exciter alternator it would still maintain excitation on this unit although it would not be entirely separate from system disturbances.

These machines have the ability to ride out system disturbances. In actual service they seem far superior in their stability, and they more readily adjust themselves to operating conditions than do those with the older style excitation.

At the end of the one-year period, the Warren generator was taken down on a prescheduled date for general inspection of turbine and auxiliaries. At this time no changes were made to the tubes or other electronic equipment except that the anode electrolysis targets in the main rectifier cooling system were replaced because they had lost approximately one-half of their active material in the one-year period. Over-all tube replacements on a periodic basis will not be made in these exciter systems as there is sufficient capacity to allow for tube failures without affecting generator output or performance.

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1. Design and Test on Electronic Exciter, Supplied From Common Shaft-Driven Generator, **A. P. Colaiaco, A. A. Johnson, J. E. Reilly.** AIEE *Transactions*, volume 69, 1950 (AIEE *Proceedings T051*).

Electric Cables for the Mining Industry

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MEMBER AIEE

RECENT years have seen rapid development of rubberlike insulating and sheath materials for cable. The introduction of polychloroprene, commonly called neoprene, has provided a sheath material that is highly resistant to heat, flame, and abrasion. The availability of polychloroprene and heat- and ozone-resistant rubbers has influenced cable engineers to review cable practice in many fields, including mining, in the light of the improved safety and economy possible with such materials.

Underground primary power in American coal mines is usually distributed at 2,300 volts delta or 4,160 volts Y, with an occasional mine using 6,900 volts delta. Formerly, the cables used at these voltages were one or more of the following:

1. Lead-sheathed rubber or varnished cambric with jute and flat-band steel or steel-wire armor.
2. Rubber insulation with rubber jacket.
3. Rubber insulation with jute and asbestos outer covering. Only occasionally were the rubber-insulated cables used with shields or ground wires.

Although many such cables are still in service, they have serious disadvantages. The steel armor tapes often corrode very rapidly due to the action of the acid mine waters encountered. The lead sheaths are often destroyed by electrolysis occasioned by the proximity of d-c haulage circuits. In addition, for such metallic-armored cable first costs are high, and, because of their weight, installation is difficult.

When the fibrous-covered types are shielded, the thin copper shielding tapes are readily exposed to the same corrosive and electrolytic conditions encountered by the lead sheaths. When such cables are not shielded there is always a possibility of corona formation and attendant cable damage. Another disadvantage of nonshielded construction is that it offers no safety features for personnel.

The disadvantages of these constructions have led to the development of a rubber cable such as that illustrated in Figure 1. This cable has ozone-resistant rubber insulation and tinned-copper shielding tapes on the individual conductors. Ground wires are placed in each of the three interstices formed by the cabled conductors. The ground wires provide a low-resistance ground-return path for fault tripping and act as a reliable means of grounding lightning protective devices. The grounded shields, besides preventing corona formation, form a covering around the conductors which is essentially at ground potential and reduce the hazard to a person who might accidentally come into contact with the exterior of the energized cable.

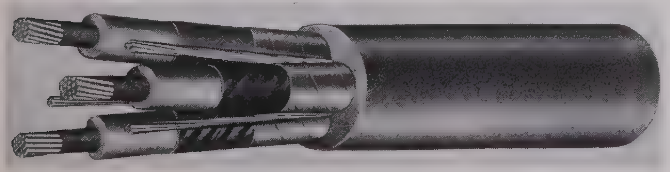

Figure 1. Mine power cable with ozone-resisting insulation, copper shielding tapes on single conductors, ground wires in the interstices; neoprene jacket over-all

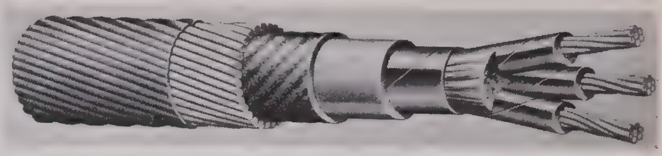

Figure 2. Three-conductor varnished-cambric lead-covered jute- and wire-armored cables for use in shafts or bore holes

The same design, with more flexible stranding of the conductors and with braided copper shields, has been adapted for use in open-pit mines to supply 5-kv power to large shovels and similar equipment. This design of portable cable is known to the industry as type *SH-D*.

The introduction of improved heat-resistant rubber and higher temperature rubberlike polycholoroprene armor has prompted some manufacturers to recommend the use of such portable cables at copper temperatures up to 75 degrees centigrade where formerly 60 degrees centigrade was recommended. This means an increase in current-carrying capacity of approximately 30 per cent with attendant economy in copper usage.

For low-voltage cables (600 volts or less) the braided types have given way almost entirely to rubber-insulated multiconductor cables with polychloroprene sheaths. These can most readily meet the severe service requirements and stringent flame-resistance characteristics required by the United States Bureau of Mines and some states.

Bore-hole cables must be supported entirely from the top. For bore holes up to about 600 feet in depth it is often feasible to use rubber-jacketed cable with shields and ground wires and to support the cable by means of the conductors (see Figure 2). For deeper bore holes the cable must be wire-armored, with the wire armor carrying the weight of the cable.

For carrying power to the bore-hole installation it is common practice to use a pole line with open-wire conductors. In heavily wooded areas, or where severe lightning conditions prevail, some mines have used preassembled aerial cable. This construction usually consists of three insulated conductors twisted together and lashed to a messenger at the factory. The cable is attached to each pole by means of messenger suspension clamps.

Digest of paper **50-108**, "Electric Cables for the Mining Industry," recommended by the AIEE Committee on Insulated Conductors and approved by the AIEE Technical Program Committee for presentation at the AIEE North Eastern District Meeting, Providence, R. I., April 26–28, 1950. Not scheduled for publication in AIEE *Transactions*.

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Variable-Speed Drive Constant-Frequency Alternator

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A CLUTCH-DRIVEN alternator, which will maintain its output frequency constant within one per cent although the driving speed varies more than 80 per cent, has been developed at the Naval Ordnance Laboratory. The 200-watt alternator is used in ordnance equipment wherein adequate mechanical power is available, but not at a constant speed. Two different types of slip clutches were developed to convert the variable-drive shaft speed to constant alternator rotor speed. Both are self-contained, require no external excitation or reference speed, and are capable of limited regulated speed adjustment.

One type utilizes a centrifugal friction clutch, wherein the driving torque is transmitted to the generator through the friction coupling of six spring-loaded friction shoes slipping on a rotating driver drum. An exploded view of the clutch components is shown in Figure 1. At any speed above the preset regulating speed, the difference between spring forces and the centrifugal forces of the shoe holders are just sufficient to produce the torque required to drive the generator. To allow for both increases and decreases in normal driving speed, continuous slip is permitted between the driver and driven drums.

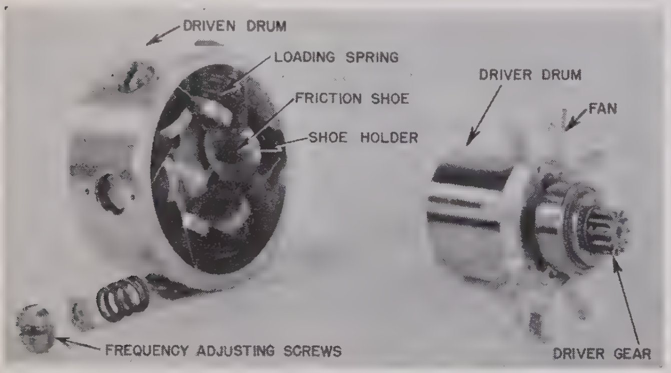

Figure 1. Centrifugal friction slip clutch, disassembled

The second method of obtaining constant driving speed is by means of the magnetic-fluid clutch illustrated in Figure 2. Clutch excitation is obtained directly from the alternator through a rectifier, and is controlled by a centrifugal contactor in series with the clutch coil. Automatic speed control is obtained by the contactor tending to interrupt the clutch current whenever the generator speed exceeds the preset value. Starting torque is provided by a small permanent magnet mounted on the clutch shaft.

For constant loads, such as the usual electronic loads, the generator speed or frequency remains constant within one per cent for drive speeds up to 80 per cent higher than regulating speed. Appreciably higher drive speeds cause excessive heating of the friction clutch or iron particle packing in the magnetic clutch. Change in generator load from full load to no load causes a 1.2-per cent rise in output speed of the friction clutch, or one-half per cent rise for the magnetic clutch. Excellent response to transient speeds or loads is characteristic of both clutches. The alternator responds to the changes without hunting or overshooting.

Limitations of the clutches arise chiefly from the power continuously dissipated as heat because of the slip speed. A temperature rise of 40 degrees centigrade is encountered. In addition, the friction shoes require replacement after about 20 hours of running because of shoe wear. Although the magnetic-fluid clutch is not troubled with wear, periodic maintenance is required because of particle separation or loss of fluid. Considerably longer service-free life can be obtained by increasing the clutch sizes. The units shown are designed for short life, intermittent duty, and hence are small physically.

The simplicity of control and the excellent transient response of the clutches commend their application in fractional-horsepower equipment, provided the losses due to slip can be tolerated. In addition to the use of the clutches for frequency regulation, they have been used successfully as voltage regulators for d-c generators driven from variable-speed shafts.

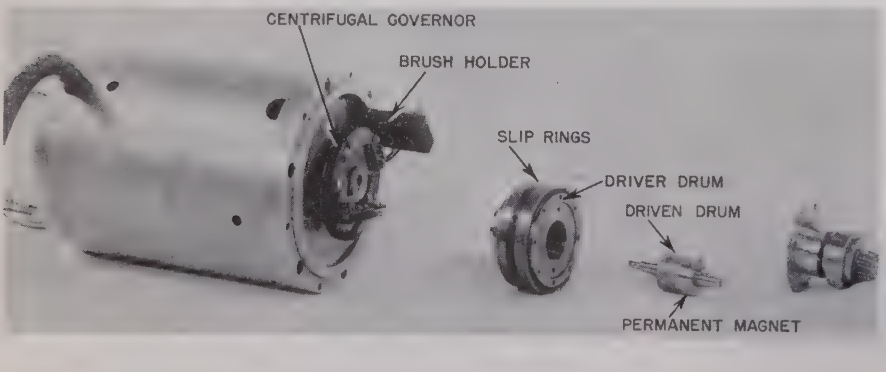

Figure 2. Magnetic-fluid clutch parts and generator housing

In this clutch a mixture of fine iron powder and oil fills the space between the two relatively moving ferrous drums. This magnetic fluid is made more or less viscous by a controllable magnetic field, whose excitation is obtained from the alternator

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Digest of paper **50-119**, "Variable-Speed Drive, Constant-Frequency Alternator," recommended by the AIEE Committee on Rotating Machinery and approved by the AIEE Technical Program Committee for presentation at the AIEE North Eastern District Meeting, Providence, R. I., April 26–28, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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Development of Useful Power From Nuclear Fission

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Plants for producing useful power from nuclear fission are being built at the present time, but research must be continued on this subject for many years before these plants can be operated with complete success. This is a problem that cannot be undertaken on a small experimental scale to perfect the process because the chain reaction is not self-sustaining on a miniature scale.

THE DEVELOPMENT of nuclear fission as an important source of useful energy is one of the great scientific and technological challenges of the world today. Here is a source of energy which is potentially capable of supplying the world's needs for hundreds of years; yet the problems of developing and proving the technical feasibility and economics are beset with peculiar difficulties, for the solution of which very little precedent exists. First and foremost is the problem of secrecy and security. The fuel for nuclear power plants is also the explosive material of atomic bombs, and the consequences of this fact have a far-reaching effect on every aspect of the task. The political problems of atomic energy are, of course, paramount, but this article will be confined to the scientific phases of the problem.

Among the technical problems, the by-product radiation which accompanies fission is the most troublesome and costly. Furthermore, the technology of such plants is entirely new, so that the materials and processes and methods for design, fabrication, control, testing, and operation must be worked out from the ground up. For all of these reasons the development of atomic power is certain to be a long and expensive venture. Finally, the atomic power plant will have to compete eventually with alternative sources of heat energy which have been refined and perfected over a long period of years of scientific and technological research and development; accordingly, the atomic power plant will have to achieve initially a corresponding degree of refinement in all of the details of its operation.

Perhaps at this point we should bolster our courage by considering the case history of the development of another energy source which now seems commonplace, but which in its infancy was faced with a somewhat similar array of problems—the petroleum industry.

The first well was drilled for oil in the United States in 1859 at Titusville, Pa., but it was over 50 years before this natural resource became a significant power source here. The important use for petroleum for a period of 30 years following 1859 was as kerosene, principally in lamps; there were only four automobiles in the entire country in the year 1894. The real development of the petroleum industry awaited the internal combustion engine and was not realized until the many scientific and technical problems of this machine were overcome, if they have been overcome, progressively during a long period of years. The internal combustion engine and its progeny, the motor car, the airplane, the diesel engine; and finally the refining, cracking, and synthesis of petroleum and its scientific exploration and discovery—it was the development of the science and technology of these problems that brought the petroleum industry to the point of real significance as a power source. The development of atomic energy as a significant power source awaits the solution of a similarly imposing array of technical problems and wil require a correspondingly long period of time.

Two important facts of nature condition the character of the atomic power development from the very beginning. One is the fact that the nuclear fission chain reaction is not self-sustaining on a miniature scale. There is no prospect, therefore, that the test tube and pilot plant stage of power plant development, during which practically all of the technical problems of ordinary industrial processes are solved, can be employed. I do not mean to imply that there is no need for a great deal of intensive laboratory work on nearly all details of the development; nothing could be farther from the truth. But the experimental plant which brings together all of the elements of the complete process is itself a large and costly undertaking which cannot be tested in miniature.

The second fact is the unfortunate necessity for radiation shielding for such plants and their associated facilities. The cost of the radiation shield varies as the logarithm of the power, and is, in any plant of practical size, an important item of over-all cost, so that even if the fission chain reaction would operate at low power the necessity for heavy and costly shielding could not be avoided entirely. These are unfortunate facts that make the development of atomic power a very costly undertaking. The very first experiment in the building of such power plants is necessarily quite a large one which will cost a great many millions of dollars, and it must be followed by subsequent scaled-up experiments which will become progressively more costly. The first petroleum from the first oil well which was drilled in this country was sold at a price of $20 a barrel. From the profits realized from

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its sale, subsequent wells were drilled, more oil was sold, and from its profits the industry grew.

This is, of course, the typical case history of successful industries. They are generally profitable even on a small scale, and the reinvestment of part of the profits in the industry permits it to grow by the progressive reduction of unit costs to the consumer, frequently accompanied by improvements in the quality and utility of the product. The development of petroleum as a source of energy, as an example, had these small beginnings which, however, could be sold for a profit from which the further development of the industry took place.

There is no such analogue in the development of atomic power. It is probable that about $200,000,000* will have to be spent in the process of building successive experimental atomic power plants before we will have a proper basis for judging the future economic possibilities of atomic energy. Because of the great array of unanswered technical questions there can be no assurance at present that the final result will be successful. If a profitable atomic industry ever develops, it is certainly decades in the future. Obviously this financial risk is one which cannot be supported by any private capital in the world, so it is clear from the outset that only the resources of the National Government can sustain the required effort. Not only does the great cost of the development make it necessary for the National Government to foot the bill, but the fact that fuel for atomic power plants is also the explosive material of atomic bombs makes it necessary for the Federal Government to control the security and accountability aspects of the project in great detail. All atomic energy work is thus the responsibility of the Atomic Energy Commission (AEC) and is carried out in laboratories operated by its contractors.

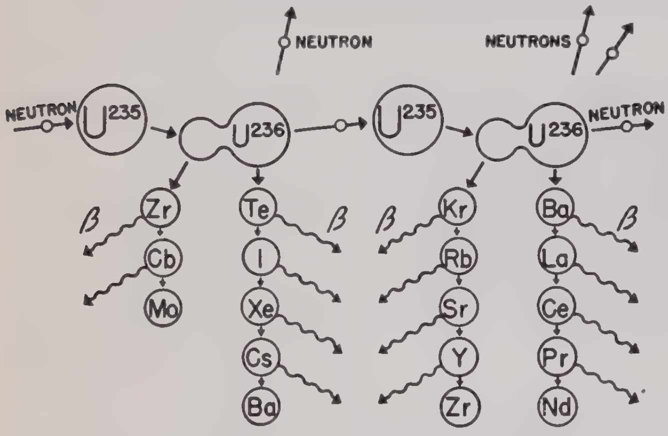

Figure 1. Simplified form of the fission chain reaction. When a neutron strikes a fissionable nucleus the two form a compound nucleus. This compound nucleus is unstable and breaks into two fragments which fly apart with enormous energy

Many aspects of the technical problem of building reactors may be inferred from a consideration of the principal elementary process, the fission chain reaction. Figure 1 illustrates this reaction in simplified form. When a neutron strikes a fissionable nucleus, for example U^{235}, the two may be presumed to coalesce to form a compound nucleus, very much the way a small raindrop might join a large one in falling through the air. This compound nucleus is very unstable and breaks into two fragments somewhat in the manner in which a large unstable liquid droplet might be divided by surface tension forces. The two fission fragments, of similar atomic weight, fly apart with enormous energy, to produce two lighter atoms near the middle of the periodic table.

The first feature of this reaction, of importance to power piles, is the following: Of the total energy for fission of about 200 million electron-volts, 80 per cent, or approximately 160 million electron-volts, resides in the kinetic energy of the two fission fragments. Although it is true that these fission fragments carry electric charge, no one has been able to figure out how to take advantage of this fact for the direct generation of electric power, so that the only alternative at present is to permit the kinetic energy of the particles to convert to heat. This kinetic energy thus appears as heat in any fission apparatus, and hence the first observation from the elementary process: (I) heat is the principal energy production in fission.

The fission-fragment nuclei have initially the high ratio of neutrons to protons of about 1.5 appropriate to the heavy uranium nucleus but unsuited to elements of much lower atomic number. Hence, these fragment atoms are unstable and undergo radioactive decay, the end point of which is a stable nucleus. In the case illustrated in Figure 1, for example, the first fission in this segment of a chain reaction produces the unstable nuclei ${}_{40}\mathrm{Zr}_{97}$ which decays by successive beta emissions to the stable nucleus ${}_{42}\mathrm{Mo}_{97}$. The other fission fragment ${}_{52}\mathrm{Te}_{137}$ decays by the same process to the stable nucleus ${}_{56}\mathrm{Ba}_{137}$. The second fission in this hypothetical case results in two fragments which eventually decay to stable ${}_{40}\mathrm{Zr}_{91}$ and ${}_{60}\mathrm{Nd}_{145}$. The detailed fission process is not identically the same in each fission event but covers a considerable range of possible mass combinations which add up to the mass of the parent nucleus. The stable end product of each fission-product decay chain shows a similar variation so that the statistical result of the chain reaction is an array of radioactive and stable nuclei which covers a broad region in the middle of the periodic table. The resulting radiation is made up principally of beta emission from a neutron–proton conversion in the nucleus but is accompanied by some gamma emission, and occasionally by a neutron.

The second property of the basic fission reaction of importance in power piles is this: (II) intense radioactivity is a necessary by-product of fission. About five per cent of the fission energy does appear in this radiation. An occasional but important neutron comes from the fission-fragment decay series with a suitable delay characteristic of the series of half-lives involved in a given decay chain. One to three neutrons are produced initially with the fission of the compound nucleus. Exactly how many neutrons occur with fission has been something of a secret because it is such an important number in calculations of chain reactions.

These neutrons produced by fission are of tremendous value and are the key to the entire situation. If we waste them by leakage from the periphery of the nuclear reactor or by parasitic absorption in the materials of construction, the pile will not react at all. The basic question of whether (on the average) at least one of the one to three neutrons produced initially would be available for a chain reaction was answered for the first time in the West Stands uranium-graphite pile at the University of Chicago. This proved the calculations which showed that if the pile were sufficiently large, so that the surface-to-volume ratio (important for peripheral neutron leakage) was favorable, and if care was used to exclude neutron absorbers, on the average at least one of the one to three neutrons per fission would be available to produce the next fission and hence propagate the chain reaction. Many other successful piles have since been built so that no one is concerned now about the first neutron per fission. The progress of the atomic age thus far has been built on this first neutron. Since one to three neutrons are produced in fission, and since only one is required to propagate the chain reaction, theoretically up to two neutrons may be left over.

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* The Atomic Energy Commission reactor program for the fiscal years 1948–49 and 1949–50 is estimated to cost $215,000,000 on the basis of authorizations approved by the Congress.

As will be shown, the development of useful atomic power focuses primary attention on these neutrons which are left over from each fission. For present purposes they are the most important of all, and in a very real sense the future atomic age depends on them. If we can build nuclear reactors which are sufficiently large and sufficiently well engineered to conserve the left-over neutrons, fission energy may become an important source of power some decades in the future. If not, the applications of atomic power will probably be limited to cases where economics is not a primary consideration. Hence a third observation from this elementary process points to (III) the necessity of conserving the neutrons left over from the chain reaction. A little consideration will serve to show why this is so. In the chain reaction, the fissionable nuclear fuel is used up to produce (*a*) heat energy (160 million electron-volts per fission), (*b*) fission products accompanied by much (*c*) radiation and (*d*) some stray neutrons which are lost to the structure or its shield.

Thus, to produce the heat energy, we destroy an atom of fissionable fuel and obtain as by-products fission fragments and radiation, both of which may be of future economic value, but which at present are expensive nuisances. Now let us consider the possibility illustrated by Figure 2, which shows the elementary process in the type of nuclear reactor which conserves and uses the left-over neutrons, the power breeder. Here, for each neutron which propagates the chain reaction, at least one is presumed to be available for a side reaction—the production of a new fissionable atom from fertile material.

This process, termed the breeding of nuclear fuel, or simply breeding, is the principal source of hope for abundant atomic power of the future. If this process can be made to work, it has many practical results. The power breeder will initially be charged with fissionable material; for example U^{235}, which will be surrounded by fertile material; for example U^{238}. Thus, as heat is produced from the fission of U^{235}, the exhausted fuel is continuously replaced by new fissionable fuel produced by the left-over neutrons.

This atomic furnace might thus produce a pound of new fuel for each pound of fuel consumed. More properly, of course, it might convert a pound of fertile material to fissionable material for each pound of fuel consumed. Since the number of neutrons left over from the chain reaction conceivably may be greater than one, the power breeder may not only replace the fuel consumed, but may, with skillful design, produce more new fuel than is consumed in the process. The fuel investment might thus be returned with interest all during the time the reactor is producing useful heat energy.

By means of a reactor program which would reinvest the fuel dividend as it becomes available, a very large power industry might be developed. Since the initial investment is thus built up by compound interest, even a very small initial deposit will grow to a very large fuel pile in the course of sufficient time. It is necessary, of course, to have an adequate supply of fertile material to stoke the atomic furnaces over this period, and the question of supply of fertile material is pertinent. If only the isotope U_{235}, present in native uranium in the concentration of one part in 140, is available as nuclear fuel, fission energy may become a significant and possible strategically important power source, but it is not likely to compare in magnitude with common fuels. If fuel breeding can be made to work, so that 100 per cent of the available native uranium and thorium can be converted to fissionable material, the total energy supply thus created will be significant in comparison to that available in coal or oil.

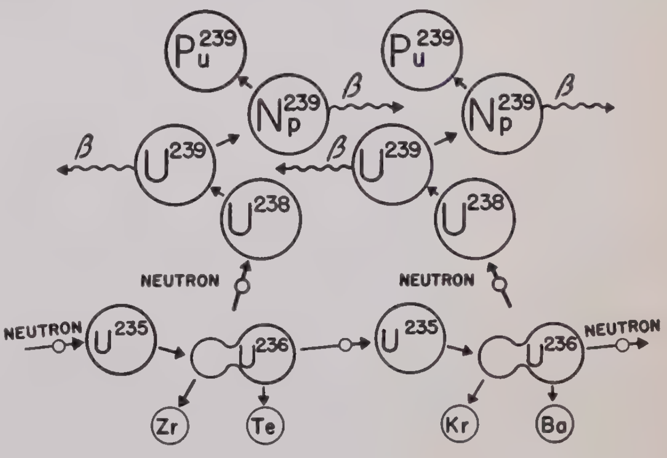

Figure 2. Fission-fragment nuclei are unstable and undergo radioactive decay. The detailed fission process is not the same in each fission event, but covers a range of possible combinations which add up to the mass of the parent nucleus

Hence, the important concepts underlying present plans for atomic power development are based on the utilization of the heat energy of fission; the necessity of coping with the problems of by-product radiation; and the necessity of conserving the left-over neutrons for fuel breeding.

The first important step in the development of atomic power will be the demonstration of the technical feasibility of high-temperature breeder reactors in experimental plants. Further in the future, these pilot plants, if success-

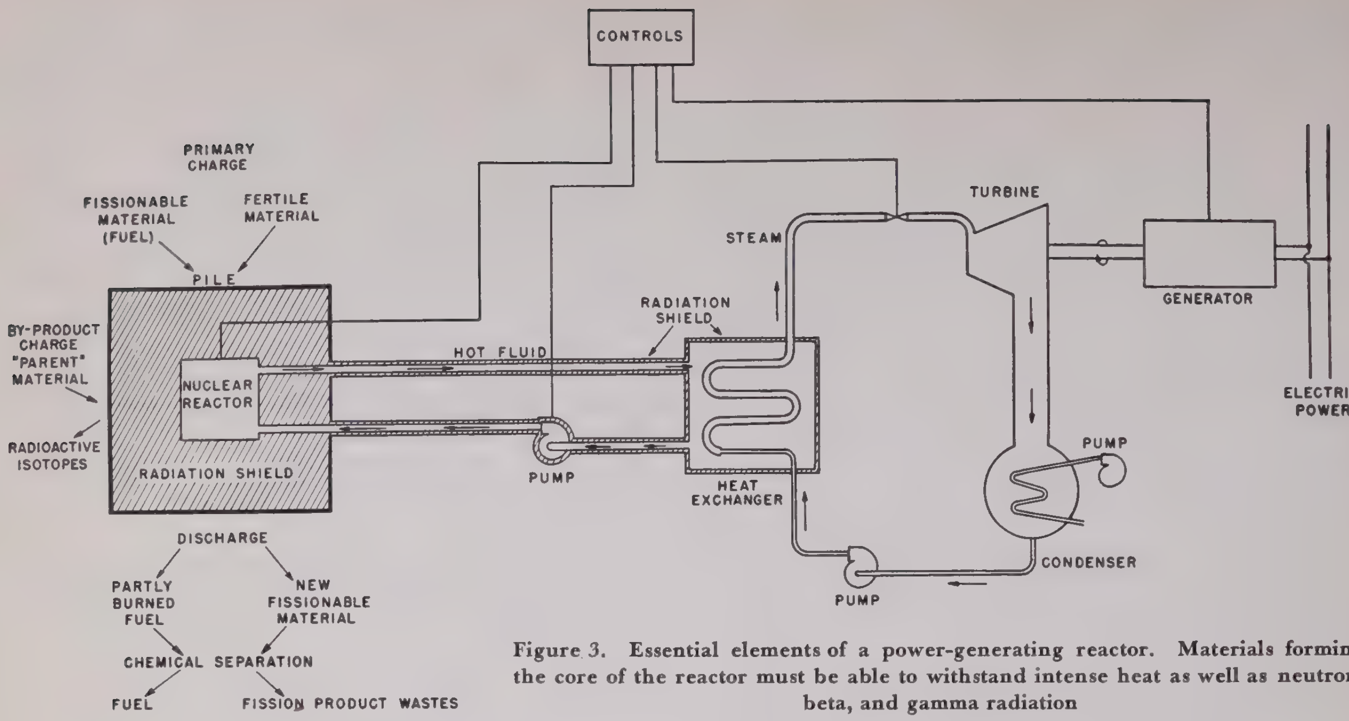

Figure 3. Essential elements of a power-generating reactor. Materials forming the core of the reactor must be able to withstand intense heat as well as neutron, beta, and gamma radiation

ful, must then be extrapolated to very large power plants, and finally the economics of the large power breeders must be developed.

The essential elements of a power-generating reactor are shown in Figure 3. The design and construction of a power reactor involves new and fascinating scientific and engineering problems at every point. In the core of the reactor the active and structural parts will be subjected to a very high temperature and to an intense flux of neutron, beta, and gamma radiation. In this environment reactor materials must not absorb neutrons appreciably and must retain strength and structural stability. In a somewhat analogous problem, materials for high-temperature steam, mercury, and gas turbines, where the parts are subjected simultaneously to very high temperatures, corrosion, and high tensile stresses, 30 years of research and development have produced an impressive array of specialized alloys for this service, most of which now can be selected from handbooks of engineering practice. The handbook of high-temperature radiation-resistant reactor materials has, of course, not been written. Much of the intensive radiation metallurgy which has been in progress in AEC laboratories since the war is providing the data which some day will fill the chapters of this book to make it as useful and practical as existing handbooks are today.

Although it is much too early to do anything but conjecture about the future economics of atomic power plants, some respects in which the first plants will be exceptionally uneconomical are quite clear. It was pointed out earlier that the fission product elements cover a broad range of the periodic table. Some of these elements have a high absorption cross section for neutrons and their accumulation in the pile will gradually poison the reaction. This loss of neutrons is wasteful since it detracts from the number available for more useful purposes; for example, breeding. One solution of this problem which will be used in early power piles is the frequent reprocessing of the fuel for the removal of these atomic ashes.

Reprocessing the fuel for the removal of fission products is an excessively costly operation, however. In fact, any simple experiment of physics or chemistry which must be accomplished in the presence of a high level of radioactivity is expensive. Consider, for example, a simple operation such as mixing two chemical reagents to form a precipitate which must be washed, collected, and dried. For nonradioactive chemicals this operation may be performed on any scale with simple and inexpensive equipment. However, if the reagents are radioactive at a level of several curies,* as an example, the simple experiment becomes cumbersome, slow, and very costly in terms of the equipment, facilities, and organizational requirements.

Before the chemist may enter the area, which is equipped with heavy shielding and remote-control gear required for radiation chemical work, he acquires a film badge and two pocket electroscopes which record any radiation exposure to which he may be subjected. He must then pass through a change room where he exchanges part of his outer garments for a special smock and shoe covers. The change room, of course, must be served by a special laundry facility which is equipped to deal with radioactive clothing, including methods for the storage or disposal of contaminants. The film badges and electroscopes must be serviced similarly by trained personnel with suitable testing and recording methods. A 1-curie level of radiation required the equivalent of about a foot of concrete shielding between the operator and his equipment. The equipment must therefore be controlled remotely by any one of a number of complicated methods, one of which is shown in Figure 4.

Because of ingenious mechanical design which has been carried out in many AEC laboratories, almost any kind of an experiment can be accomplished remotely. The cost of this equipment and the heavy shielding with which it must be used is, however, very great, and worse still the time required to set up a given experiment, perform the manipulations, and clean up later, adds greatly to the cost of the work. Finally, the chemist, upon leaving the radioactively hot area, must remove his protective clothing and check his hands and feet for contaminating activity.

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* The curie is the unit of radioactivity and is almost exactly that of one gram of radium. More precisely, it may be defined as the amount of radioactivity when 3.7 $\times 10^{10}$ disintegrations occur per second.

In the case postulated, the water (or other liquid) used to wash the precipitate will be contaminated, and the disposal of this waste raises a serious and as yet unsolved problem. An inspection of half-lives of the radioactive elements in typical fission-decay series discloses a range from fractions of a second to thousands of years. Although an initial period of storage will permit the decay of short-lived activities, any reduction in activity in the stored wastes realized in this way is obtained at the very considerable expense of the storage facilities. Some of the activity is of such longevity that no practical period of storage will serve to eliminate it as a hazard. The traditional method of dealing with wastes is to throw them away, and the trouble with radioactive wastes is that no one has yet found a safe place to throw them.

Any examination of the elements of cost of an atomic power plant will show that the radiation shielding and remote control equipment and methods imposed by the presence of radiation are inordinately large items. Our success in dealing with this problem in the future eventually will have an important bearing on the economics of atomic power.

It is true that there is some low level of waste activity which may be discharged to the air or to a river without hazard. The determination of this safe radiation level is always somewhat conjectural, and as a result present standards are probably very conservative. It is clear that zero level of radiation is not attainable, since a practical minimum is set by the natural radioactivity of the earth, cosmic radiations, and especially the natural activity of radio potassium found in most foods and in body tissue.

At present, the solution of this problem is being deferred in favor of the more urgent matter of making a high-temperature reactor work. If power reactors do work and become economical some decades hence, the disposal of an energy content in radiation comparable to the energy production in electricity will have to be dealt with successfully. Like the atomic bomb, there is little prospect that the problem of disposing of radioactive wastes can be ignored in the hope that somehow it will go away.

The manifold difficulties in the way of the development of atomic power are more than matched by the ingenuity and enthusiasm of the scientists and engineers who are dedicating their efforts to this Herculean task. There is no dearth of ideas or plans for the solution of all of the problems which now confront us, and certainly one can see clearly, if somewhat distantly, a progressive line of improvement in power reactors which will lead far beyond any now on the drawing boards. However, it is vitally necessary to prove reactor designs, by construction and operation of suitable prototypes, so that future improvements will be based on a sound foundation of experience. The Atomic Energy Commission's reactor program, which was announced some time ago, includes four reactors, all of which will contribute important information to the design of future power reactors. Quoting Dr. L. R. Hafstad, AEC Director of Reactor Development, these four projects are the following:

1. The first has been designated as a materials testing reactor, called *MTR*. While it is itself an experimental reactor, as its name implies, it is intended also to give information on the behavior of materials in reactors so that larger and more powerful special-purpose reactors may be built ultimately.

2. The second reactor is a land-based prototype of a reactor for use in propelling naval vessels. It would be a simple, single-purpose reactor designed specifically and solely for the purpose of producing large amounts of heat under conditions which will permit conversion to propulsive power.

3. The third reactor is a single-purpose experimental reactor designed specifically to give us information about the breeding process. This reactor at the present time is the most likely to demonstrate the actual breeding of new fissionable material. It is, however, neither a high-power reactor nor designed for the purpose of demonstrating appreciable amounts of useful power though an incidental amount of power may be produced by a by-product.

4. The fourth reactor is the more ambitious project—the Knolls Atomic Power Laboratory reactor. This reactor is intended to produce a really significant amount of electric power. At the same time, it is hoped that it will be able to demonstrate at least partial success in breeding. This reactor is, therefore, a very complex device since its design represents a compromise between the demands for power production and for breeding. If successful, however, this project would represent a major step forward in the direction of the production of useful power without depleting, and perhaps even increasing, our national supply of fissionable material for any purpose.

This last reactor project has been somewhat altered in objectives since this report was issued. The application of atomic power plants to ship propulsion has become an immediate goal. Power reactor development is the largest single activity of the Knolls Atomic Power Laboratory (KAPL), operated by the General Electric Company for the Atomic Energy Commission at Schenectady, N. Y. The test site for reactors developed by KAPL is located 18 miles north of the city, on a 4,500-acre plot of marginal farm land adjacent to the Adirondack forest preserve. The construction of a power reactor is a major technical task and

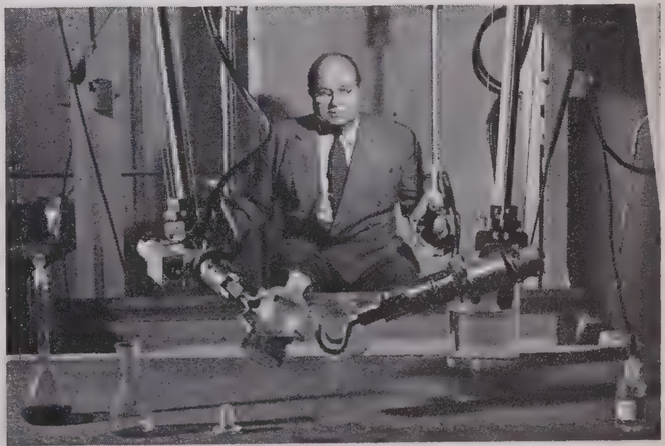

Figure 4. Equipment which is used for remote control of apparatus to protect the operator from radiation

will require several years of intensive effort. In the development and design of such plants, great effort is being made to solve the many engineering, design, and operating details sufficiently well to permit their ready extrapolation to large power reactors.

The term "fuel breeding" will be defined further. While the one to two neutrons left over from the fission chain reaction are theoretically available for fuel breeding, whether they are practically available for this purpose depends upon the knowledge and skill of the reactor scientists and engineers. Every structural and active material that goes into reactors must be examined and tested with great care for its parasitic neutron absorption, for no matter what other virtue a reactor material may have, it must not waste neutrons.

This examination of a material, for example, iron, must extend not only to the iron itself, but to the practically unavoidable impurities of iron, some of which may be very harmful even in very small concentration. The components of a reactor structure thus contribute to the neutron economy and will in aggregate determine how many of the left-over neutrons are available in practice for fuel breeding. Some of the measurements which enter into the tabulation of neutron losses are so difficult to make with precision that no final answer to this question can be determined except from studies of an experimental breeder reactor in moderately high-power operation.

In addition to the Knolls reactor, power development reactors are being designed at the Argonne National Laboratory, operated by the University of Chicago for the AEC, and in the Atomic Power Laboratory being operated in Pittsburgh by the Westinghouse Electric Corporation for the AEC.

All of these reactor development groups will, of course, depend on the other national laboratories of the Atomic Energy Commission for assistance. Thus, the development of atomic power is a project which will draw upon the combined resources of industrial and government scientific and engineering knowledge and experience.

I shall not indulge in any predictions concerning the ultimate future of this great scientific and engineering experiment. In arriving at one's own conclusions, however, one should bear in mind that the attainment of the goal of useful power from nuclear fission will not be based solely on what we know today, but rather on what we know today plus what we are going to learn in two or three decades of scientific progress. The latter must be weighed heavily in judging the future possibilities of any development of this magnitude.

Sensitive Ground Protection

AN AIEE COMMITTEE REPORT

A Project Committee of the AIEE Committee on Relays has collected information on available methods for sensitive ground relaying of 3-phase distribution and transmission systems. Several reliable methods for transmission circuits and unigrounded as well as ungrounded transmission systems have been reviewed. The limitations of presently known systems for the protection of 3-phase 4-wire multigrounded systems, as well as some results of investigations concerning "arc frequency relaying" which need further experimental study, are indicated.

IN THE FALL of 1946, a working group was appointed to study present-day sensitive ground protection of 3-phase systems and to prepare a report on this subject. It was realized that the Project Committee would not be able to find new solutions to some of the problems, but it was believed that it would be helpful to summarize present-day practices and to give an indication where developments and improvements are necessary or desirable. A number of papers which concern certain phases of sensitive ground protection have been published during the last ten years which describe in detail some of the fine points not repeated in this report.[1–10]

Sensitive ground protection as dealt with in this report comprises relaying of ground faults (that is, either the indication of the faulted feeder of a system, or its automatic switching off) with fault currents to ground of a magnitude in the order of about one per cent of the normal or full-load current of the feeder. This will mean, in general, that the primary fault current will be between one and ten amperes. The main objectives of sensitive ground protection are the following:

1. Limitation of physical damage and reduction of number of sustained faults.

2. Facilitation of joint use with communication circuits. The degree of sensitivity proposed herein greatly exceeds the

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Full text of paper **50-70**, "Sensitive Ground Protection," recommended by the AIEE Committee on Relays and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 30–February 3, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

Personnel of the Project Committee of the AIEE Committee on Relays: Eric T. B. Gross (*Chairman*), C. J. Berghs, R. J. Cooper, T. R. Halman, P. A. Jeanne, Cort Lowerison, W. K. Sonnemann, A. R. van C. Warrington.

requirement of positive operation at 50 to 100 amperes in five seconds or less.[1,2]

3. Disconnection of broken conductors on the ground or on grounded objects. This is important on circuits along or crossing school yards, playgrounds, highways, and so forth.

4. Co-ordination of branch fuses, relaying, and reclosing cycles of substation circuit breakers. This may be accomplished by temporarily locking out the sensitive ground relays rather than by settings above the minimum blowing of branch fuses.

GROUND RELAYING

Analyses of transmission system faults have indicated a mode fault resistance of about 20 ohms with less than five per cent of all faults exceeding a resistance of 90 ohms. This analysis was made[3] on many systems ranging from 26 to 220 kv. As a general rule adequate ground relaying of transmission circuits may be obtained with the more conventional methods and equipment.

With few exceptions, only distribution or subtransmission systems will be so grounded that sensitive ground protection will become necessary. The fault current to ground is comparatively small in the following systems:

1. Delta systems (ungrounded systems) of small or moderate mileage. The fault current is small in such systems since it is the result of the capacity-to-ground of the system. The magnitude of the fault current to ground can be estimated for single-circuit overhead-line systems from the "rule of thumb" formula:

$$I \text{ amperes} = \frac{\text{miles times kilovolts (line-to-line)}}{160}$$

2. Systems unigrounded through high impedance.
3. Resonant grounded systems (as defined in AIEE Standard *32*).[4]
4. Effectively grounded systems (as defined in AIEE Standard *32*) having high fault resistances, in particular in some multigrounded 4-wire systems. Small fault currents result in many cases from indirect grounds without a conductor on ground (grounds with high fault resistance).

In systems as described in items 1, 2, or 3 unbalances of the primary loads, and even more so their effects on the secondary side, are so small that the ground relay, if connected in the common return of three identical, paralleled current transformers (four current transformers in case of 4-wire circuits), will measure correctly the ground fault current of the particular feeder. Greater accuracy may be achieved economically by cable-ring transformers.[5] Another solution is 3-phase[6] current transformers.

1. Delta Systems. Very satisfactory experiences have been gained with an installation of ground relays in ungrounded, radial delta systems of 13.8-kv operating voltage. These relays are of the directional type since they must operate only in the direction to the fault. The relay sensitivity is high enough to permit relay operation on ground faults of considerable contact resistance. In many cases the fault current to ground was so small that the fault on the feeder, which had been recognized by the relay, could be found only after temporary solid grounding of another phase and repeated switching in on the fault had produced sufficiently great damage to indicate the location of the fault.

2. Systems Unigrounded Through High Impedance. In order to make possible the positive indication of ground faults, extensive tests were made by the Southern California Edison Company and a relaying system developed where grounding of 3- or 4-wire systems could be limited to one station. This system was originally planned for radial systems[7] and later extended to mesh systems by the use of carrier channels.[8] The fault current to ground is kept below approximately four amperes. The grounding reactance is designed to take into account the capacitive single-line-to-ground fault current of the systems, and is low enough to produce a residual fault current which is lagging (inductive). The whole grounding system is basically a greatly overcompensated resonant grounded system, with the ground relays acting under the influence of the quadrature component of the residual feeder current.

3. Resonant Grounded Systems. Sensitive directional ground relays[9] may be used in resonant grounded systems. With this type of protection the relays operate on the in-phase component of the residual current.

The relays used in the foregoing systems are very similar, the main difference being that a different component of the residual current is used in each case to produce maximum positive torque, namely, the leading quadrature component of the residual current in system *1*, the lagging quadrature component of the residual current in system *2*, and the in-phase component of the residual current in system *3*. To the relay terminals of the second (polarizing) coil of this directional-type relay is supplied the voltage from neutral to ground (zero sequence voltage of the system) in all three cases in the same manner, or sometimes the current in the neutral of the grounding device.

Many operators of delta and high-impedance or resonant grounded systems feel that neither a circuit nor a major part of a circuit should be disconnected to remove a low-current ground fault. A sensitive relay scheme is desirable. If the ground persisted and if desired a source of ground current sufficient to blow branch fuses with low-resistance faults could be connected to the system for a definite time and removed. In any event an alarm would be sent in and operating personnel dispatched to locate and correct the fault condition.

4. Effectively Grounded Systems Having High Fault Resistance. The greatest problem in 4-wire multigrounded systems[1] is that high-resistance ground faults and load unbalances have similar current magnitudes so that grounds are difficult to recognize. In a small number of systems multigrounding has been eliminated and relay schemes are used quite satisfactorily[7] as described in item 2. In many cases, systems operate with multiground common primary and secondary neutrals where only ground relays with current settings that are considerably higher than "sensitive ground protection" prevent relay operation on load unbalances.[1] However, fault currents to ground may be too small for relay operation if, for example, they are on a dry roadway or in contact with trees, and it is this kind of fault which makes improvements and new developments desirable.

Since it is difficult to distinguish between load unbalances and high-resistance grounds, in a multigrounded system a relay scheme which uses other than 60-cycle currents may lead to a satisfactory solution of this problem. Though a successful method of securing selective ground indication has not yet been found, it should be mentioned that tests have been made with devices which utilize the fact that arcs to ground produce high frequencies which are not present, to the same extent at least, under conditions of load unbalances. Two different kinds of equipment were tested. The one consisted of a carrier-frequency receiver with coupling capacitors and traps so that the arc frequencies would be recognized. With this arrangement, it was found that the equipment reacted also without grounds on the line when equal frequencies were produced by apparatus not connected to the line, as, for example, passing streetcars. The other kind of equipment utilized the high-frequency current supplied from the secondaries of current transformers and filters which would eliminate low frequencies. However, it was found that not only the arcs of ground faults, but also harmonics present in the ordinary load current, actuated the relay. The relays used had to have broad frequency response since different types of arcing faults did not produce the same frequencies so that tuned relays would not be satisfactory. It is evident that extensive development and study will be necessary to clarify further possibilities of "arc frequency relaying." It should be highly desirable to continue with these experiments and tests, since they may show the way to a solution.

CONCLUSIONS

The following conclusions may be drawn from the data and analysis presented herein:

1. A reasonable sensitivity in relay protection against ground faults is highly desirable to improve service through reduction of the number of sustained faults.
2. Fault resistances on transmission systems (at 26 kv and above) are such that desirable sensitivity of ground relaying may usually be obtained with conventional schemes.
3. Fault resistances of a grounded conductor may be very high on distribution systems requiring unusual equipment and methods to provide the desired sensitivity of ground relaying.
    (*a*). Ground relaying on delta systems, resonant grounded systems, and systems unigrounded through high impedance may be provided with sensitive directional product relays, giving proper attention to current characteristics. Residual voltage devices may be used in some cases.[10]
    (*b*). Grounded neutral systems, with 3-wire circuits, or 4-wire with the neutral grounded at the supply point only, may be relayed sensitively by a number of methods such as current-polarized directional ground relays with means to prevent relay damage on heavy currents, cable-ring transformers, special 3-phase current transformers, and so on.
4. Multigrounded 4-wire distribution circuits offer the most severe problem in securing sensitive ground relaying because of unavoidable unbalances in load current and residual transients when a circuit is reclosed.
5. Radical departures from conventional methods have been tried, such as devices responding to harmonics generated by arcs, but no practical success with these has yet been reported. In the present state of the relaying art, it is believed that there is no practical method of securing sensitive ground relay protection for 4-wire multigrounded distribution circuits.

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Nonmagnetic Mass Spectrometer

A 3-stage nonmagnetic mass spectrometer, employing the principle of velocity selection, has been developed by the National Bureau of Standards. In the new spectrometer a radio-frequency field replaces the usual magnetic field. The instrument has promising applications in several fields of science and industry. One of these applications offers a way to settle the question of the chemical composition of the upper atmosphere. This is a problem which is directly related to work in radio propagation and stratospheric flight. Arrangements have been made with the Applied Physics Laboratory of the Johns Hopkins University to send one of the new spectrometers aloft in a rocket. Before it is mounted in the rocket, the spectrometer tube will be evacuated and sealed; when the rocket has reached maximum altitude, an arm of the tube will be broken open to the rarefied air. The relative densities of atmospheric components will then be telemetered back to the ground for recording. The spectrometer is now being adapted to the rapid scanning of mass spectra. Present methods permit sweeping twice a second through the mass range from 10 to 50, displaying the measured mass components directly on the screen of a cathode-ray oscilloscope. The scanning is accomplished by sweeping the ion accelerating voltage from 50 to 250 volts while modulating the radio-frequency potential with a 1,000-cycle per second signal.

Design and Control of Ferroalloy Furnaces

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FERROALLOY furnaces form a special group of electric furnaces in which the electrodes are buried in the charge instead of standing over a bath of molten metal as they do in the steel melting furnaces. The main part of the energy is used to perform chemical reactions, such as the reduction of ores, and the subsequent combination of the resulting elements with iron or other elements such as carbon, and so forth.

Ferroalloy furnaces are used for the manufacture of various alloys such as ferrosilicon, ferrochrome, ferromanganese, silico manganese, calcium silicide, and calcium carbide. They are relatively simple in construction. The furnace installation, see Figure 1, consists of transformer, bus bars, flexibles, electrode leads, holders, electrodes, furnace, collecting equipment, and control mechanism. Each part of the equipment demands careful designing.

The furnace itself is simply a large crucible, generally of carbon, built of cut blocks or formed with paste. In some cases the ore used in the process is used for the crucible, for instance in the manufacture of ferrochrome or calcium carbide. When carbon is used it must be backed by refractory brick in order to keep the heat from escaping.

The most important part of the furnace from an electrical point of view is the bus bars. They must carry heavy currents with as little voltage drop as possible. The operating qualities of the furnace depend in large measure on the design of the bus bars because they determine the normal power factor of the installation.

Voltage, current, power input, electrode diameter, and crucible area are related by reasonably simple equations which are based on the current-carrying capacity of the electrode and the fact that for a certain definite product there is a simple relation between electrode diameter and load resistance.

Most alloy furnaces in the United States are designed with three electrodes since large distributing systems are generally of the 3-phase type. In the French Alps, however, where the metallurgical companies own their own power equipment, a large number of single-phase furnaces are operating. It is there that the large 10,000-kw Miguet Perron single-phase furnace was developed. The electrode in this case carries 200,000 amperes.

Alloy furnaces can be represented by a circuit with constant reactance and variable resistance, and their electrical behavior can be determined by the usual circle diagram. The point of maximum power input is generally close to the point of normal operation, and the furnaces are, therefore, very sensitive to a change in primary voltage.

Regulation of alloy furnaces is obtained by moving the electrodes up and down. Raising the electrodes reduces the power input and conversely. They can easily be controlled by automatic regulators which work from a change in current. When the current increases above normal the electrodes are raised, and when the current drops below normal the electrodes are lowered.

The operation of an alloy furnace depends on a great number of factors. The most important are analysis and size of raw materials, homogeneity of mix, voltage, current, and electrode position.

To manufacture a product of constant properties it is essential that the analysis of the raw materials be closely controlled. Their size will determine the speed at which the reactions will take place and also the space available for the escape of the gases. The power input must be as constant as possible to keep in step with the flow of materials. The relation between voltage and current must correspond to the resistance existing in the furnace.

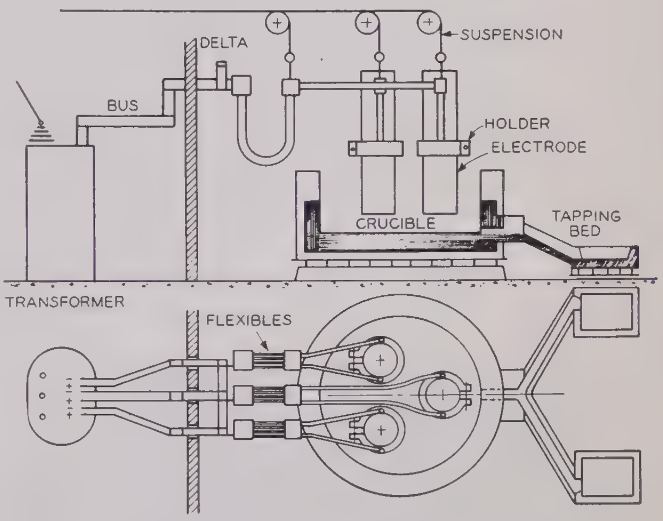

Figure 1. A typical ferroalloy furnace

The position of the electrode determines in a certain measure the temperature in the heart of the furnace. The electric energy which leaves the tip of the electrode is transformed into heat energy and thus becomes available for the performance of the desired reactions. These reactions are generally the reduction of some oxide and the subsequent combination of the resulting metal with iron or carbon, or some other element such as calcium. The necessary temperature varies with the nature of the process which is being used.

Alloy furnaces are economically justified when the temperature of the reaction is higher than can be obtained by mineral fuel or where special conditions obtain.

Digest of paper **50-86**, "Design and Control of Ferroalloy Furnaces," recommended by the AIEE Committee on Chemical, Electrochemical, and Electrothermal Applications and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 30–February 3, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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Electronic Synchronous Speed Regulator

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A SPEED REGULATOR for a d-c motor driving an a-c generator which will maintain the frequency of the alternator output voltage in synchronism with a frequency source of low power output is described in this article. This is accomplished, in general, by obtaining a voltage proportional to the phase angle between these two frequencies and using this voltage to adjust the field current of the d-c motor, and hence the speed, in such a way as to keep the phase angle constant. By controlling the phase displacement or integral of the speed rather than the speed itself, maintenance of synchronism is ensured, since any steady-state variation in the circuit parameters will be compensated for by a change in the steady-state value of the phase angle.

A number of precision speed controls have been described in the past, some of which use the same basic circuit to be given here.[1-3] It appears, however, that these controls were applied, for the most part, to small machines only, that is, of five kilowatts or less. The earlier papers give little indication as to the performance obtained at that time, and it is thought that the present system presents a considerable improvement over these earlier systems in both stability and damping. When the basic circuit was tried on the motor-generator set used here, it was found to be unstable and useless for the purpose for which it was required. Various methods of improving the performance were investigated, and the control to be described here was developed. The control system given here has been found capable of maintaining a 30-kva alternator (0.8 power factor) in synchronism with a reference frequency, with a transient error of less than one-half of a cycle during a step load variation of ten kilowatts.

An electronic speed regulator for a d-c motor which drives an a-c generator has been designed to maintain the frequency of the output voltage in synchronism with a low-power frequency source. Synchronism is ensured by controlling the phase displacement rather than the speed of the driving motor.

PHYSICAL ASPECTS OF THE CONTROL SYSTEM

The Controlled Components. The regulator was developed primarily to obtain a source of 60-cycle standard-frequency power of good wave form and capable of delivering up to 25 kw. The problem was to synchronize a 550-volt 30-kva 0.8-power-factor 60-cycle sine-wave alternator driven by a 220-volt 40-horsepower d-c motor with a 60-cycle standard-frequency voltage derived from a crystal-controlled oscillator.

The transient operation of a d-c motor under either field-current control or armature-voltage control is characterized by a time constant which is a combination of several machine parameters. This time constant is given by a well-known equation

$$T_M = \frac{JR_A}{K_V K_T} \tag{1}$$

where T_M is the time constant of the d-c motor, R_A is the resistance of the d-c motor armature circuit, K_V is the counter electromotive force per unit angular velocity of the d-c motor, and K_T is the torque per unit armature current of d-c motor.

For the normal d-c shunt motor with no connected load, this usually works out to be less than one-twentieth of a second. However, for the machine cited here, the alternator, or load, inertia was found to be about six times that of the d-c motor alone; hence it would be expected that the time constant of this motor generator would be about one-third of a second. Probably because of the added resistance of the d-c armature voltage source, this time constant actually was measured at about 1.1 seconds. With the addition of cumulative compounding, which gives more stable operation, this may be increased to about 2.5 seconds.

The use of field-voltage control of the speed introduces a second major time constant into the system because of the inductance of the field windings. Since the regulator acts only for small variations about the normal speed, this time constant must be evaluated in the saturated region of the flux characteristic. This time constant was determined experimentally by frequency-response methods and was found to be about 0.228 second.

It is interesting to note here that this time constant does not represent the lag between the field current voltage. The field current contains components which are caused by the coupling which exists between the field windings and the pole face windings, the pole core, and so forth. This yields a transfer function between field current and field voltage which consists of two time constants, but fortunately, the second constant, being determined by the parameters of the secondary circuits, is small; and, in this case, it was estimated to be about 0.05 second. The flux-field voltage transfer function, which is of most importance here, remains a simple time constant.

Essentially full text of paper **50-25,** "An Electronic Synchronous Speed Regulator," recommended by the AIEE Committee on Industrial Control and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 30–February 3, 1950. Not scheduled for publication in AIEE *Transactions.*

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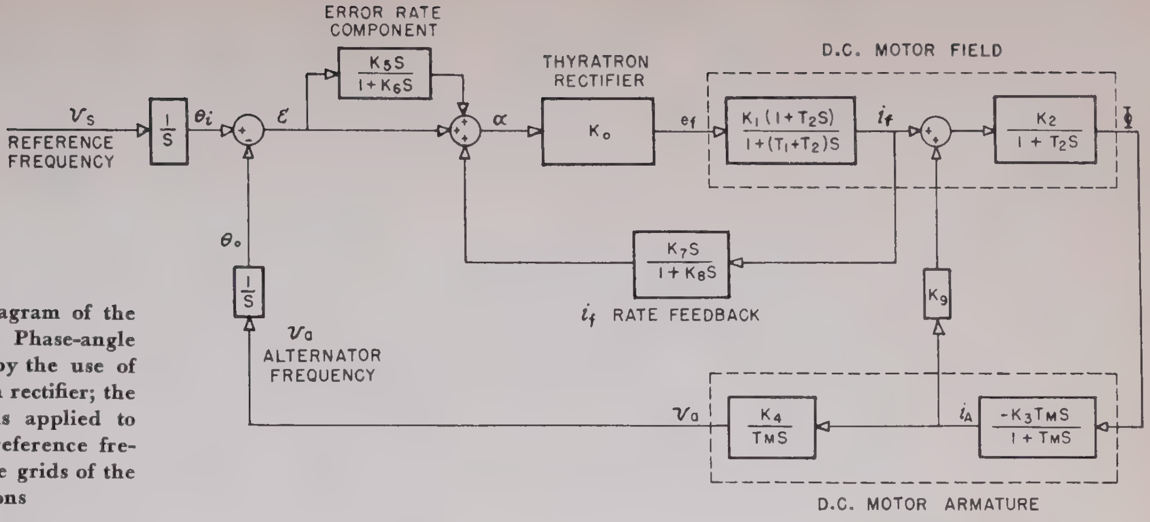

Figure 1. **Block diagram of the main control system. Phase-angle control is obtained by the use of a full-wave thyratron rectifier; the alternator voltage is applied to the plates and the reference frequency voltage to the grids of the thyratrons**

The use of field voltage control complicates the theory to some extent by introducing nonlinearities in the form of products between two variables into the system equations. It has been shown elsewhere[4] that these nonlinearities may be approximated by a linear relationship over a small range, however, and the transfer function of the d-c motor which is controlled by the field voltage has been given as

$$v_a/e_f = \frac{K}{(1+T_fS)[1+T_MS(1+T_AS)]} \qquad (2)$$

where v_a is the angular velocity of the alternator output frequency in electrical radians per second, e_f is the voltage applied to the d-c motor field, T_f is the time constant of the d-c motor field circuit, T_M is the time constant of the d-c motor, and T_A is the time constant of the motor armature circuit.

The term T_A in this case was found to be small enough to be neglected.

This transfer function presents the over-all relation between speed and field voltage. This may be broken down into components as shown in Figure 1.

The Controller. The regulator generally may be divided into two parts: the main phase control and the auxiliary controls. The main control loop and its associated stabilizing circuits is primarily responsible for the maintenance of synchronism. The auxiliary circuits, on the other hand, consist of a load-compensating device and an automatic synchronizer.

Phase-angle control is obtained by using a full-wave thyratron rectifier in which the alternator voltage is applied to the plates and the reference frequency voltage is applied to the grids. Thus the power for the control comes from the alternator itself, and the drain on the source of reference frequency is negligible. The output voltage of the rectifier is applied across a resistance which is common to both the rectifier circuit and the field circuit. The gain of this component, which is also the gain of the main control loop, is varied by suitably proportioning the amount of voltage from the thyratron rectifier which appears in the field circuit.

As was pointed out previously, this control in itself was unstable under conditions where the gain was increased sufficiently to give the degree of static stiffness suitable for compensating for load and d-c line voltage variations and changes in machine constants. Stabilization and adequate damping are obtained by error rate or anticipatory feedback and also feedback proportional to the rate of change of the variable just after the first inherent time delay. These quantities are converted into voltages, added and amplified, and introduced into the rectifiers as a d-c bias control.

The stabilization obtained by this means is sufficient to allow step load variations up to about five kilowatts without loss of synchronism. However, the maximum gain compatible with the desired stability was not enough to give adequate compensation for large load variations by mere

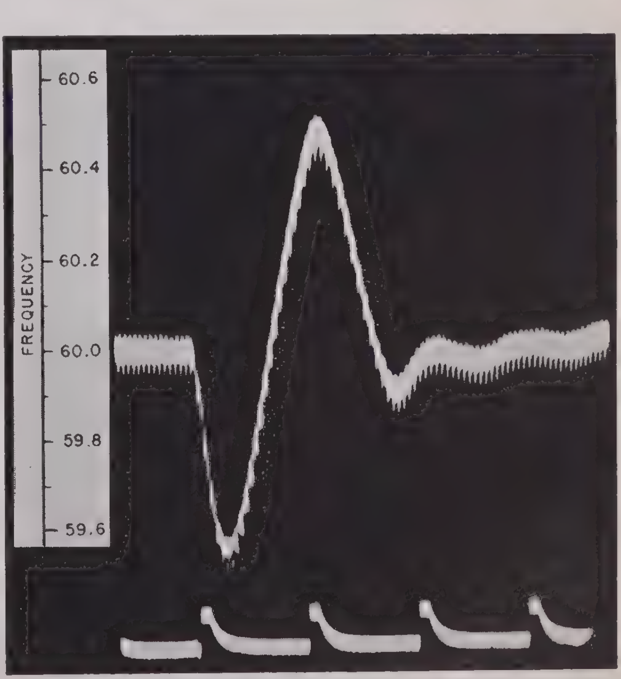

Figure 2. **Increased stability attained by both error rate and field current rate feedback allows a step-load variation of ten kilowatts without loss of synchronism**

All timing wave markers are at one-second intervals

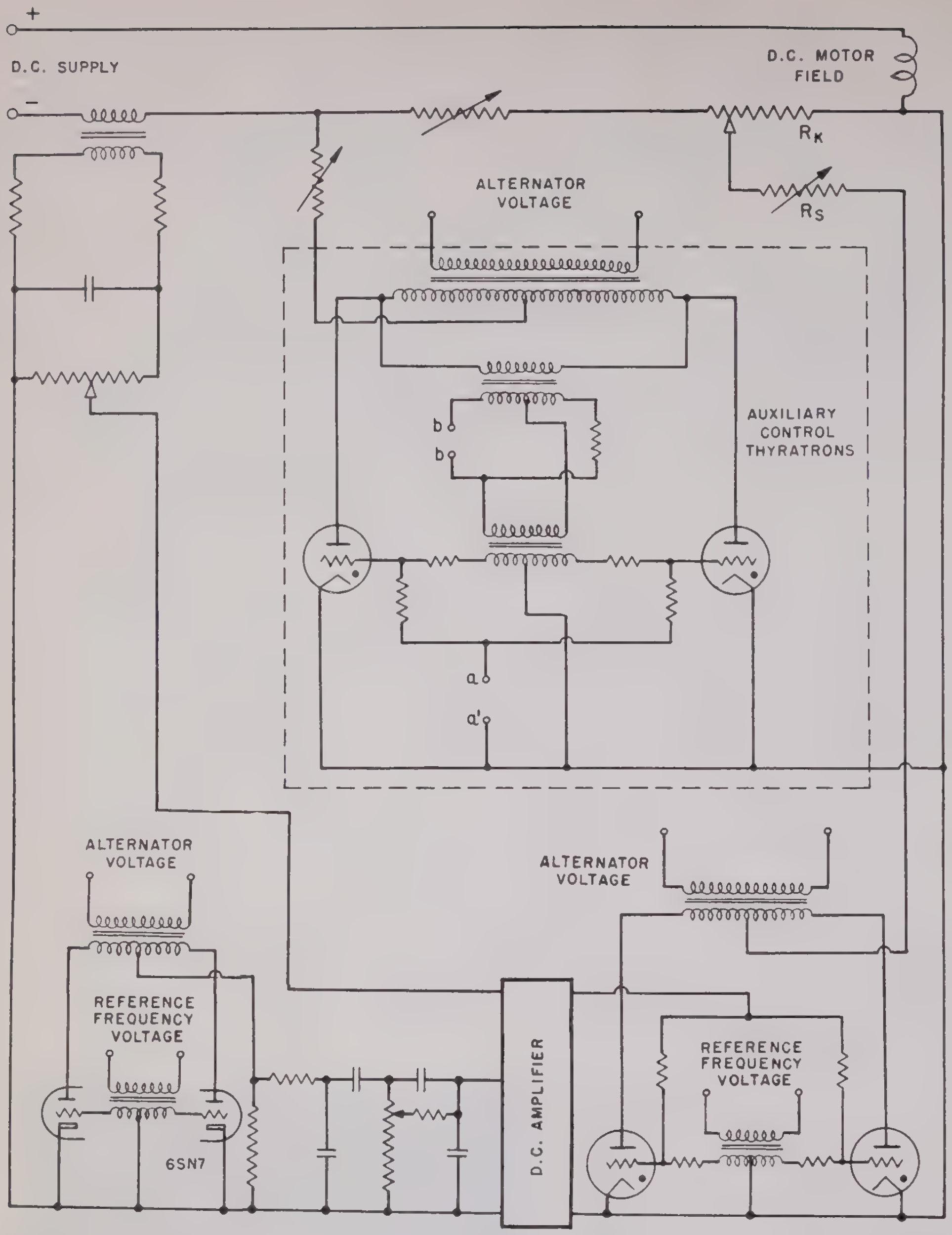

Figure 3. **The schematic diagram of the controller shows the way the reference frequency voltage is applied to the grids of the thyratron rectifiers to attain the main control**

changes in the steady-state value of the phase angle. Therefore, load compensation was introduced by a second thyratron rectifier using an electronic 3-phase watt-sensitive detector to control a saturable reactor in a phase-shift network feeding the auxiliary thyratron grids.

In addition to the load compensator, an automatic synchronizer was used which, in the absence of phase control, maintained the speed of the machines at a value sufficiently close to synchronous to enable the main controller to seize control when energized. This device was included so that the phase controller would regain synchronism should the system fall out of step because of the application of too large a step load. The synchronizer uses as a detector a Wien frequency bridge tuned to 60 cycles. The output of the bridge circuit is passed through a phase-sensitive device, and the resulting d-c output is applied as a bias control to the auxiliary control thyratrons.

Since the output of the synchronizer is essentially proportional to the speed, this device also introduces output rate feedback into the controller as a whole. The increased stability attained is sufficient to allow a step-load variation of ten kilowatts without loss of synchronism (Figure 2).

Over-all Performance. When all components are in operation the over-all performance of the regulator allows the alternator to be loaded up to rated value in 10-kw steps with a transient frequency error of less than one-half cycle. Larger step load variations result in the controller dropping a cycle or so before regaining synchronism. D-c line voltage variations have the same effect as load variations, a 5-per cent step rise in voltage giving a transient frequency error which will be less than one-quarter of a cycle.

THE PHASE ANGLE CONTROLLER

The circuit of the phase-angle controller is shown in Figure 3, and the complete control loop is shown in block form in Figure 1. The main control is effected directly through the thyratron rectifier circuit by using the reference frequency voltage to fire the thyratrons. The gain of the main control loop may be varied by suitable adjustment of the resistors R_S and R_K and through the selection of a suitable plate voltage for the thyratrons.

The error-rate component is a duplication of the thyratron rectifier circuit in miniature, using a double-triode vacuum tube in place of the thyratrons. The output of this circuit is smoothed and differentiated by a resistance-capacitance network, suitably amplified, and applied as a bias control on the main thyratron circuit. Filtering required in this device is heavy, due to the pulsed nature of the vacuum-tube output, and the frequency range over which the device introduces a leading phase angle is limited. Although the circuit is crude and nonlinear in behavior, it stabilized the main loop considerably.

Following the work of Hanna, Oplinger, and Valentine,[5] derivative feedback from a point just after the first inherent time delay was added to the system by using a special transformer in the field circuit to provide a voltage proportional to the rate of change of field current. It was found that this improved the damping of the system considerably even though the field current contained components which were not proportional to flux.

THE AUTOMATIC SYNCHRONIZER

The circuit of the automatic synchronizer, which features a Wien bridge as a frequency detector, is shown in Figure 4. The output voltage of such a bridge either lags or leads the applied voltage depending on whether the applied frequency is above or below the normal, and hence a phase-sensitive circuit is required to differentiate between overspeed and underspeed. The remainder of the circuit accomplishes this and gives either a positive or negative direct voltage depending on the phase of the Wien bridge output. This is applied as a bias control on a second set of thyratron rectifiers to adjust the field current suitably.

This device increases the stability of the system by introducing output rate feedback as well as acting as a secondary form of speed control whenever the main controller has temporarily lost control. Since the whole system is primarily a regulator where the input is constant, the output rate is equivalent to error rate, and this device adds a further lead component to the over-all transfer function. In fact, the active frequency range of the two lead components are adjacent and they complement each other.

An examination of the behavior of the phase controller shows why the automatic synchronizer is required. If the speed is below synchronous, the thyratron in the phase-angle controller will be fired every time the reference vector slips past the alternator-voltage vector and will deliver full output voltage which will tend to raise the speed. However, if the speed is above synchronous, the thyratron output voltage will be maximum whenever the reference vector coincides with the alternator voltage vector, thus increasing the speed and increasing the error.

THE LOAD COMPENSATOR

Since the alternator which was used for this application is of the 3-phase type, a device which is sensitive to the sum of the true power output of all three phases is necessary in order that adequate compensation for all types of 3-phase loads will be provided. A circuit which will accomplish this is shown in Figure 5. It is a 3-phase version of a simplified form of a single-phase electronic wattmeter

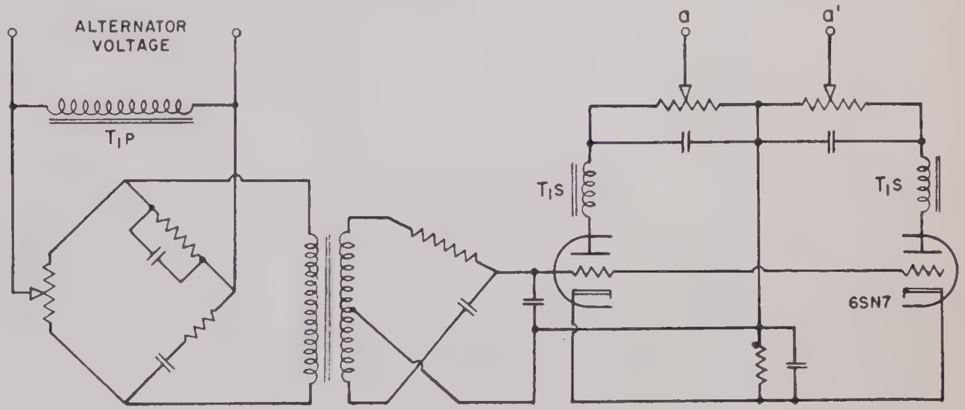

Figure 4. The circuit of the automatic synchronizer features a Wien bridge as a frequency detector. This device which increases the stability of the system acts as a secondary speed control when the main controller is temporarily out of synchronism

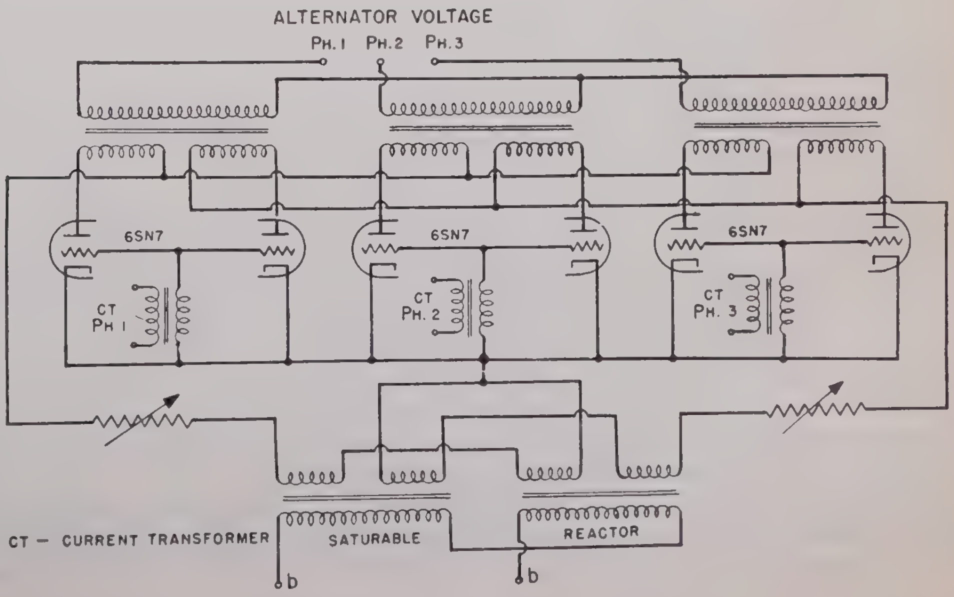

Figure 5. In order to compensate for 3-phase loads, a circuit which is sensitive to the power output of all three phases is used; the alternator output voltage is applied to the plates of the vacuum tubes, and a correctly phased voltage proportional to the load current is applied to the grids

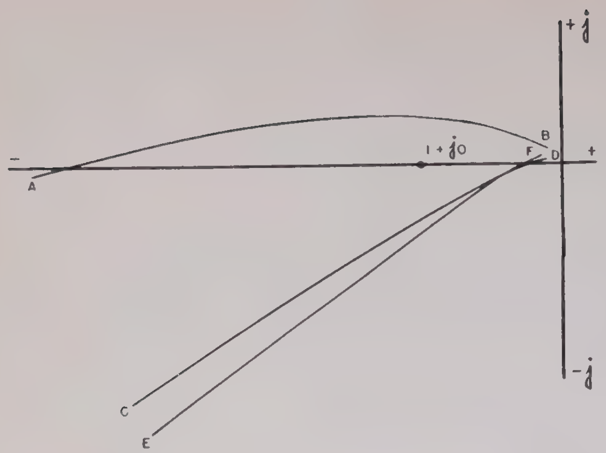

Figure 6. Plot of the transfer function of the main control loop in the frequency plane shows that the system is unstable according to Nyquist's theory (curve *AB*). The control function of the system stabilized by means of error rate compensation is shown by line *CD*; the control function of the system using feedback to reduce the field time constant is plotted as line *EF*

given by Malling.[6] The plates of the vacuum tubes are energized by the alternator output voltage and the grids are excited by a voltage proportional to the load current. These quantities must, of course, be correctly phased. The output of the detector is used to control a saturable reactor for phase-shift control of the second set of thyratrons.

DESIGN CONSIDERATIONS

The first consideration in the design of this type of regulator is the selection of the main control loop components and examination of the main loop as a whole to determine what gain and other parameters are necessary to satisfy the specified steady-state requirements of the system. Secondly, the transfer function of the main control loop alone must be studied by any of the well-known methods to determine what degree of stability exists, and, thirdly, if this is not satisfactory, methods of improving the stability and damping must be developed. Except for the choice of gain the constants involved in the first two steps are predetermined and invariant. However, the third step allows for considerable ingenuity in the choice of methods and apparatus.

In the electronic synchronous speed regulator given here, the main disturbances which influence the design are output load variations, line-voltage variations, and temperature variation of d-c field-circuit resistance. The degree of these disturbances for which the regulator is required to compensate determines the gain of the main control loop.

Since a load-compensating element is provided, the output load variations are of little importance in determining the gain as far as steady-state variations are concerned, although the gain will be influenced by the maximum impulse load which can be absorbed, since there is a time lag in the operation of the load compensator. However, the main loop alone must be able to compensate for line-voltage variations, and it is convenient to base the preliminary choice of gain on this premise. Having done this, the effect of other disturbing factors may be considered.

In order to calculate the gain required to compensate for a specified line-voltage variation, it is necessary to have only the open-circuit characteristic of the d-c machine, the resistance of the field, and the steady-state field current/speed relationship in the vicinity of synchronous speed. A change in line voltage will influence the speed by changing not only the voltage applied to the armature, but also the voltage applied to the field circuit. Fortunately, the effects of these two tend to cancel each other.

The method of calculation can best be shown by example. Suppose that a 10-per cent variation both above and below normal line voltage may be expected and that the regulator should compensate for this variation by a change in the steady-state phase angle of not more than 90 degrees. This value is only one-half the total allowable phase-angle variation, but some allowances must be made for overshooting and other possible disturbances which may occur at the same time. The total line-voltage variation is then 20 per cent of 220 volts, or 44 volts. From the open-circuit characteristic, it is found that the field current must change by one ampere. If the field-circuit resistance is 73.5 ohms, the change in field current due to the change in applied voltage will be only 0.6 ampere. The remaining 0.4-ampere variation must be accomplished through a phase-angle shift and consequent change in output of the thyratron rectifier. If the speed/field current proportionality constant is 66.7 radians per second per ampere, then the over-all gain of the main loop becomes

$$K=\frac{0.4\times 66.7}{\pi/2}=17 \text{ radians per second per radian} \qquad (3)$$

The gain has the dimensions of $(\text{Time})^{-1}$, since the main loop control is of the integral type.

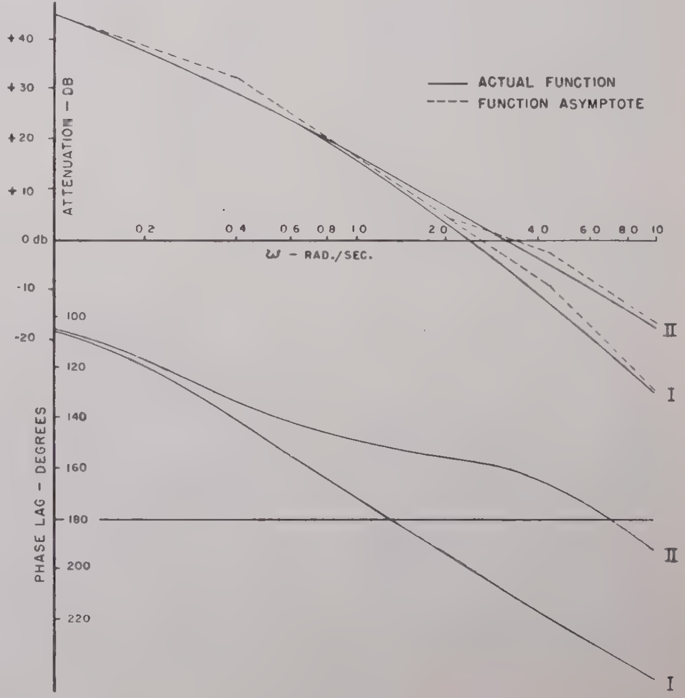

Figure 7. The transfer function asymptotes of the unstabilized system (I) are compared with those of the system with error-rate stabilization (II)

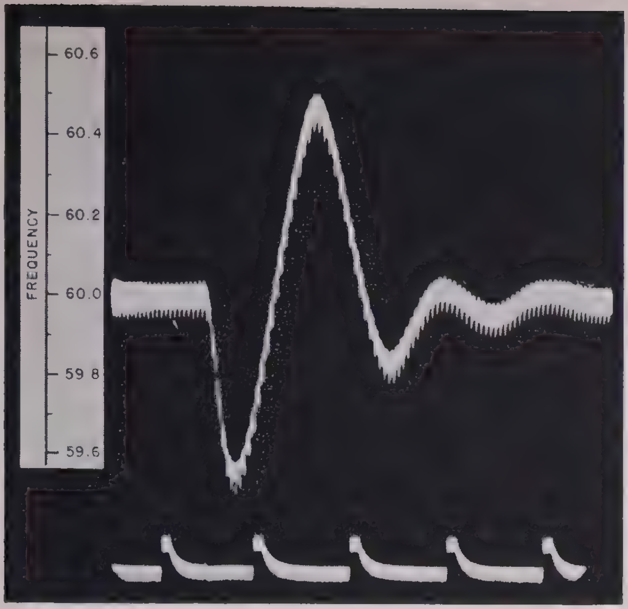

Figure 8. By comparing this oscillograph made when a 10-kw step load is applied to the alternator that has no field current rate feedback to Figure 2, the damping effect of this type of feedback may be seen

The transfer function of the main control loop may now be written

$$\frac{17}{S(1+2.5S)(1+0.228S)}$$

A plot of this function in the frequency plane reveals, according to Nyquist's theory, that the system is unstable (curve *AB*, Figure 6). Therefore, the transfer function will have to be modified if the control system specifications are to be met.

One of the most useful methods of stabilizing a closed-loop system is to introduce a correction proportional to the rate of change of error in addition to the signal proportional to the error alone. As a rule, error rate can be introduced only over a small frequency range, since it is usually necessary to reject undesired higher frequency "noise" signals. For purposes of example, it will be assumed here that a lead component with a ten-to-one frequency range, which is reasonable, is added in cascade to the control system. The transfer function then becomes

$$\frac{17}{S(1+2.5S)(1+0.228S)}\;\frac{1+\beta S}{1+0.1\beta S}$$

The effect of this component is to add a leading phase angle to the main transfer function over a frequency range whose limits are determined by the value of β. A criterion has been given[7] for obtaining the optimum value of β which states that the unity-gain line on the logarithmic plot of attenuation versus frequency should intersect the −6-decibel-per-octave section introduced into the transfer function asymptote by the lead component at a point about one-third of its length from the high-frequency end. The most suitable value of β can be obtained by cut-and-try methods on a plot of the uncompensated transfer function. Figure 7 shows the transfer function asymptotes of the unstabilized system and the system stabilized by this method, as well as the actual shapes of these two functions. Replotting the stabilized control function on the Nyquist diagram (curve *CD*, Figure 6) the degree of stability obtained is shown.

It is evident from Figure 7 that the length and position of the −6-decibel-per-octave section introduced into the function asymptote is dependent not only on the system gain required, but also on the value of the field time constant. Since the length of this −6-decibel-per-octave section determines to a large degree the amount of lead introduced, further improvement in performance usually can be had by reducing the value of the time constant which determines the position of the break point at the high-frequency end. This may be accomplished by using derivative feedback from the field current. The line *EF* on the Nyquist diagram (Figure 6) indicates the improvement which results from using this type of feedback to achieve a reduction of about 12 per cent in the value of the field time constant. Comparison of Figure 2 with Figure 8 shows the greater damping effected by this means.

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Waves Reflected Around Mountain

While engineers still have not found a convenient way to move mountains, they have done the next best thing. A microwave communication system installed between a substation and generating plant of the Pennsylvania Electric Company at Johnstown has shown the reflection principle to be both efficient and economical. The substation and generating plant are 12 miles apart and multiple telephone lines for control purposes would have been expensive. Microwaves seemed to offer a solution, but these waves travel only in a straight line and at the Johnstown installation there is a large hill between the substation and the generating plant. Since the waves would not go over this hill or through it, the beam was reflected around it. In operation the microwaves are beamed at a large aluminum reflector sheet placed two miles from the substation. This 20-foot square sheet is mounted on a 50-foot tower and is in the "line of sight" of both the substation and the generating plant. Microwaves striking this mirror-like reflector are deflected around the side of the mountain to the receiving apparatus.

Application of Magnetic Amplifiers

F. N. McCLURE

The effective application of modern magnetic amplifiers in industry depends upon a clear understanding of the operation of the self-saturating circuit, characteristics of core materials and rectifiers, and performance characteristics of the complete magnetic amplifier. This article discusses these factors and some diversified industrial applications.

MAGNETIC amplifiers, which proved so valable in servomechanism equipments during World War II, are being increasingly used as components in all sorts of control and regulating circuits. Today, engineers are uncovering potential uses for these static amplifiers in practically every electrified industry in the United States.

Although the simple saturable-core reactor has been known and applied for years, the renewed interest in the use of magnetic amplifiers can be attributed to three major factors:

1. The self-saturating circuit, which makes possible high values of power gain, was very little used and certainly not generally understood in prewar applications of magnetic amplifiers. The general feeling was that the increased power amplification obtained by adding feedback would result in an increased time delay in a device which was already too slow. Actually, it has been found that feedback can be used to increase the ratio of amplification to time delay.
2. The performance of self-saturating magnetic amplifiers depends greatly on the core material and rectifiers used. The recent developments in core materials and dry-type rectifiers have made it possible to capitalize on the self-saturating circuit. These new materials are largely responsible for the tremendously high gains now possible.
3. Industry is ready for such a device. Electronic control in industry is very well established. However, certain applications stand out where an amplifier would be more practical if it were permanent and maintenance-free. This is especially true in heavy industries such as steel and paper.

Two self-saturating magnetic amplifier circuits are shown in Figure 1. The upper circuit, which produces an a-c output, differs from a simple saturable-reactor circuit in that rectifiers are added in series with the two a-c windings. The lower circuit is one of several self-saturating circuits which produce a d-c output. Standard rectifier circuits can be transformed to self-saturating magnetic amplifier circuits by the addition of a saturable reactor. The circuit shown uses a center-tapped transformer full-wave rectifier circuit. Self-saturation can also be obtained by using feedback windings carrying rectified load current.

The operation of the self-saturating magnetic amplifier is most easily understood by analyzing the circuit shown in Figure 2. This circuit is referred to as a half-wave self-saturating circuit. It is not a practical circuit because of the fundamental frequency voltage induced in the d-c circuit. For purposes of analysis it will be assumed that the added impedance Z in the d-c circuit is sufficiently large to reduce the alternating current resulting from this induced voltage to some negligible value.

Other assumptions are

1. Zero resistance in the a-c and d-c windings.
2. The load resistance R is small in comparison with the unsaturated impedance of the a-c winding.
3. Rectifiers are assumed to be perfect—zero forward resistance and infinite back resistance.

If the core material is assumed to have an idealized hysteresis loop as shown in Figure 2, the analysis is simplified. Consider first the case of zero control current. The a-c circuit is closed at voltage zero at the beginning of a positive half-cycle. As the supply voltage increases, the flux increases from zero in accordance with the volt-seconds absorbed by the reactor until saturation induction is reached. Up to this time the load current is limited by the high un-

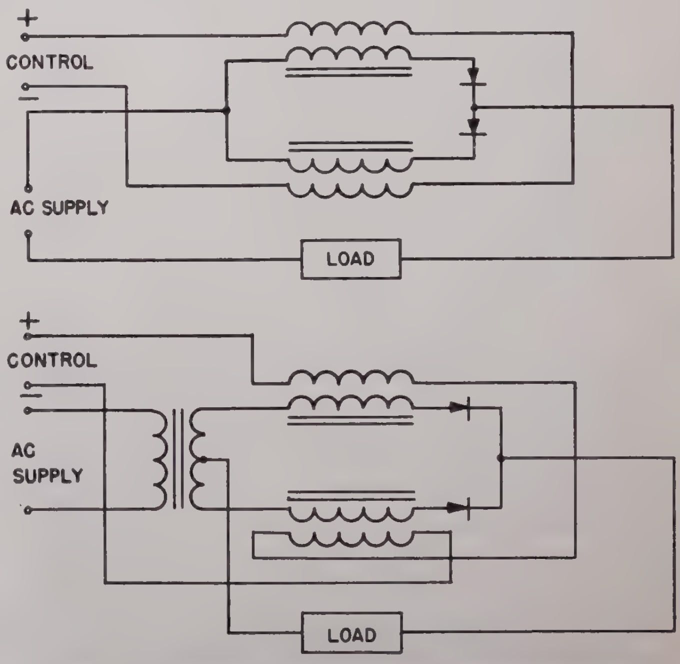

Figure 1. Magnetic amplifier circuits with self-saturation

Full text of a District paper, "Application of Magnetic Amplifiers," presented at the AIEE Great Lakes District Meeting, Jackson, Mich., May 11–12, 1949.

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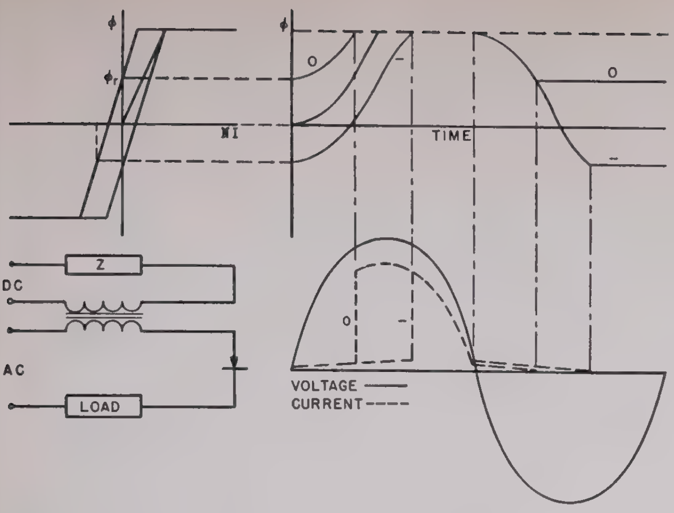

Figure 2. Operation of the half-wave self-saturating magnetic amplifier

saturated impedance of the a-c winding. After saturation flux density is reached, the current is limited only by the load resistance and follows a sine wave. The current wave is not shown for the conditions during the first cycle since it does not reoccur during subsequent half-cycles because of the effect of hysteresis. As the voltage and current decrease, the flux follows the upper branch of the hysteresis loop. When the load current reaches zero, the flux has a value equal to the residual flux, Φ_r. The current does not reverse during the negative half-cycle of supply voltage because of the rectifier.

During subsequent positive half-cycles of voltage the flux rises from an initial value Φ_r until saturation flux density is reached. As described previously, the current up to this time is limited to a small value by the unsaturated impedance of the winding. At saturation the current rises sharply to a value determined by the supply voltage and the load resistance and follows a sine wave. After the current decreases to a value corresponding to the knee of the upper branch of the hysteresis loop, it is again limited by the unsaturated impedance of the winding. The current goes to zero when the flux reaches its initial value, Φ_r.

For a negative control signal the value of flux at zero voltage at the beginning of a positive half-cycle is determined from the upper branch of the hysteresis loop as shown in the diagram. As the voltage rises, it now takes a longer time for the flux to reach saturation since the change in flux is proportional to the volt-seconds. The current rises from its initial small value at a later time than with zero control current, resulting in less average current through the load. Thus, the voltage appearing at the load can be varied from near zero to practically full supply voltage by varying the d-c control current from a small negative value to a small positive value. The output current is very similar to that of a grid-controlled rectifier. Reverse current during the negative half-cycle of voltage causes the flux to reach a value less than that assumed in the preceding analysis. This increases the time required for the flux to reach the saturation induction, decreases the average value of load current for a given d-c signal, and thus, decreases the power amplification.

Although this analysis has been made for a simple half-wave circuit with idealized conditions, the operation and wave forms obtained with actual full-wave circuits are very similar. The oscillograms of Figure 3 illustrate the load-current wave form obtained in a simplified self-saturating magnetic amplifier using toroidal Hipernik V alloy cores. The oscillogram on the left was obtained with zero control current and the one on the right with a small negative signal.

Better core materials and dry-type rectifiers have done much to make magnetic amplifiers more useful in industry. New and improved core materials have made it possible to build amplifiers of higher amplification which has increased the flexibility of the device. The d-c magnetization curves for some of the core materials used in magnetic amplifiers are shown in Figure 4. Hipersil alloy is a grain-oriented silicon steel widely used in power and distribution transformers. It is particularly useful where relatively large amounts of power are involved and low cost is important. Hipernik alloy is a 50-per-cent nickel-iron alloy. Mu-metal alloy and Mo-permalloy are representative of the 74 to 80-per-cent nickel alloys. These materials have a lower saturation flux density than the others.

Hipernik V alloy is a grain-oriented 50-per-cent nickel-iron alloy. The composition is the same as Hipernik alloy, but the material differs in that it is drastically cold-reduced and specially annealed. Hipernik V material has been commercially produced in thicknesses of 0.005, 0.002, and 0.001 inch. Comparing the guaranteed properties of Hipernik V alloy on Figure 4 with regular Hipernik alloy, it can be seen that the magnetization curve for Hipernik V alloy has a very sharp knee which is reached at a low value of magnetizing force and is nearly flat beyond the knee. Regular Hipernik alloy, on the other hand, has very high permeability at low inductions but saturates slowly. Magnetic amplifiers using Hipernik V alloy cores have a higher amplification and a greater region of linearity than amplifiers using conventional magnetic materials, but because of the great amount of cold rolling, the high purity of the material, and the special anneal, the material is more expensive.

During the past decade new dry-type rectifiers have been developed and the old ones improved. The rectifiers most commonly used in magnetic amplifiers are the germanium and selenium types. Modern rectifiers are manufactured more uniformly than was possible previously, which is important because differences in rectifier characteristics affect amplifier operation. The rectifiers should have low forward resistance and high back resistance, since back leak-

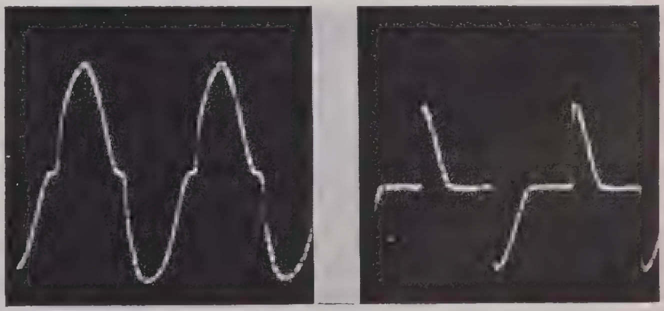

Figure 3. Load current wave forms of a self-saturating magnetic amplifier

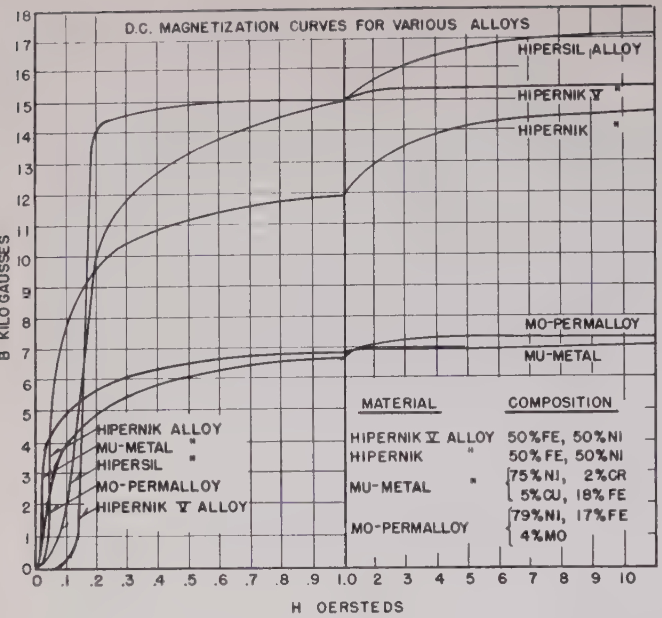

Figure 4. D-c magnetization curves for various alloys

age reduces power amplification. They should maintain these desirable characteristics with aging and exposure to the environmental conditions encountered in the application where they are used. Vacuum-tube rectifiers have also been used where the magnetic amplifier is applied for reasons other than replacement of an electronic amplifier.

In order to show the effect of using different core materials in magnetic amplifiers, four amplifiers with toroidal cores of Hipernik, Hipernik V, Hipersil, and Mu-metal alloys were tested. These were chosen as being representative of materials most commonly used. The four amplifiers were made as nearly alike as possible. When using Hipernik V alloy, the cores must be placed in some type of container, so that the material is not strained while winding the coils. Cores of the other materials were also placed in Micarta resinous plastic boxes so that the coil dimensions would be the same in all of the amplifiers. A lower a-c supply voltage was required with the Mu-metal alloy amplifier because of the lower saturation flux density.

There is little to be gained by the use of the better core materials in magnetic amplifiers without feedback. This is not the case when using the self-saturating circuit. The transfer curves (output versus input) of Figure 5 show the effect of using different core materials in self-saturating magnetic amplifiers. The transfer curve of the Hipersil alloy amplifier has a lesser slope than the others and, therefore, the amplifier has a lower amplification. The transfer curve for the Mu-metal alloy amplifier is steep, indicating a high amplification, but the wattage output is less than the others because of the lower saturation induction of the material. Although the slopes of the nearly straight line portion of the transfer curves for Hipernik alloy and Hipernik V alloy are about the same, the transfer curve for Hipernik V alloy is nearly straight over a much larger range.

Every magnetic amplifier has an optimum load resistance which results in maximum power output. This optimum resistance is dependent on the range of control current. The curves of Figure 6 illustrate the optimum load resistance for a self-saturating magnetic amplifier with different values of d-c control current. The optimum load resistance is approximately equal to the impedance of the remainder of the circuit near saturation.

There is an inherent time delay in magnetic amplifiers resulting from the inductance of the windings. Since in most cases the rise of load current with a suddenly applied control voltage is not exponential because of the nonlinearity of the circuit, the term "time delay" is commonly used rather than "time constant."

The time delay of an amplifier can be decreased by adding resistance in the control circuit. However, the addition of resistance results in reduced amplification. When high values of power gain are obtained by using self-saturation, the increased amplification is accompanied by increased time delay. A change in the length of the effective air gap causes a similar change in the amplification and time delay. Although a change in amplification is always accompanied by a change in time delay, the relationship between the two quantities differs depending upon the method used.

The curve of Figure 7 shows the effect of adding resistance in the control circuit of a magnetic amplifier with simplified self-saturation. It should be noted that a large increase in the ratio of amplification to time delay can be realized by using self-saturation and then reducing the amplification by the addition of resistance in the control circuit. With no feedback the amplifier has an amplification of eight

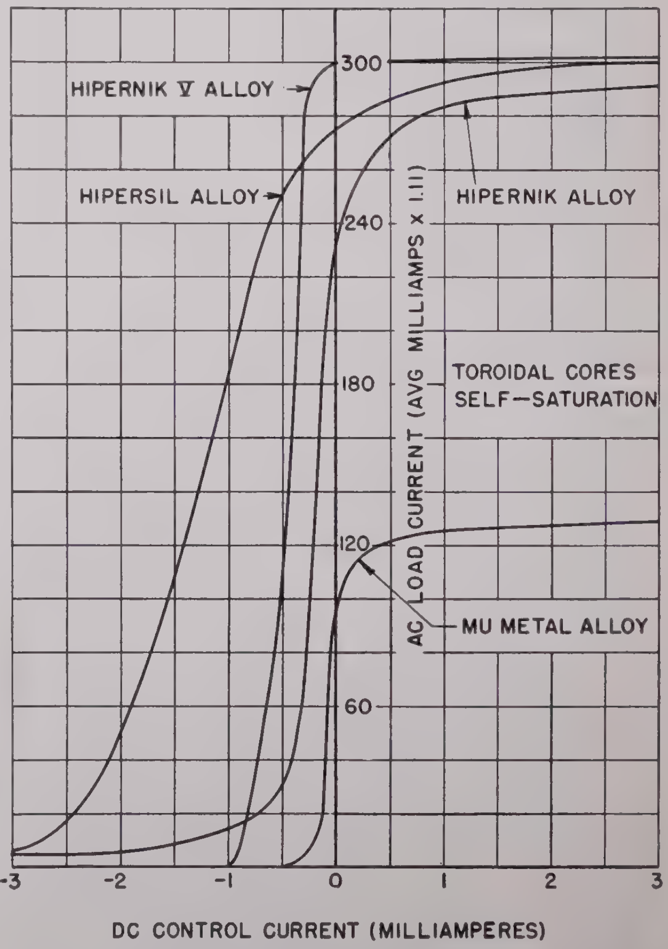

Figure 5. Transfer curves of self-saturating magnetic amplifiers using various core materials

and a time delay of 3.8 cycles. When self-saturation is added, the amplification is increased to 1.42×10^4 and the time delay is 45 cycles. As resistance is added in the control circuit, the amplification and time delay are reduced, but when the time delay has been reduced to 3.8 cycles (the time delay with no feedback), the amplification is of the order of 1,000. At this point the ratio of amplification to time delay is about 100 times its value with no feedback.

Many applications such as voltage regulators require a magnetic amplifier whose d-c output voltage will reverse in polarity with a reversal of input. Such a circuit is shown in Figure 8. The circuit is essentially made up of two full-wave bridge self-saturating magnetic amplifiers connected so that one side produces an output of one polarity and the other produces an output of reverse polarity with a reversal of input. This circuit requires two machine fields, each capable of supplying full excitation. Bias windings have been omitted for simplicity. If space is not available in the machine for the oversized field, then the two fields in the figure can be replaced with appropriate resistors and the machine field connected across the outside terminals. In general, balanced magnetic amplifiers have low efficiency.

The current transductor is a device which effectively transforms d-c primary current into an a-c secondary current by d-c saturation of the core. It is essentially a magnetic amplifier in which the d-c ampere-turns are produced by the d-c bus passing through the cores and the load is an ammeter.

The schematic diagram is shown in Figure 9 together with an ideal saturation curve. The theory involved is most easily explained by the use of this ideal curve in which the flux reaches saturation at an infinitely small value of magnetizing ampere-turns and remains practically constant at this value as the magnetizing ampere-turns are increased. The a-c coils are so wound that for a given half-cycle the a-c ampere-turns on one core aid the d-c ampere-turns while they oppose on the other. Referring to the saturation curve, it is seen that the coil in which the ampere-turns are aiding will have no back voltage induced since there will be no change in flux. The current in the opposing coil will increase until the a-c ampere-turns equal the d-c ampere-turns so that a back voltage is induced as the flux changes along the vertical axis. Therefore, the a-c ampere-turns must equal the d-c ampere-turns and the a-c ammeter can be calibrated to indicate the current flowing in the d-c bus.

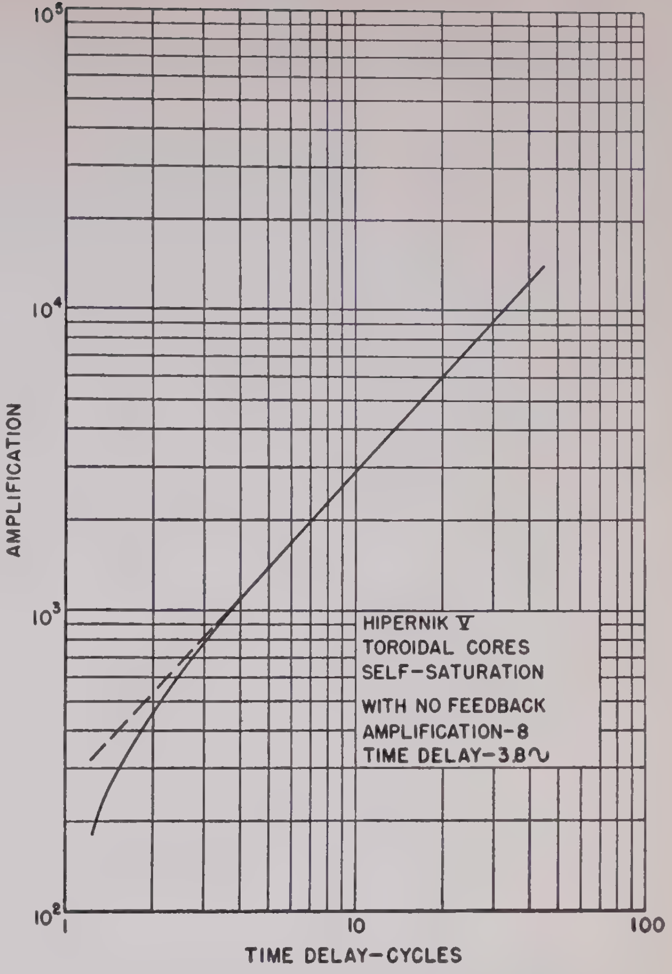

Figure 7. Effect of adding resistance in the control circuit of a self-saturating magnetic amplifier

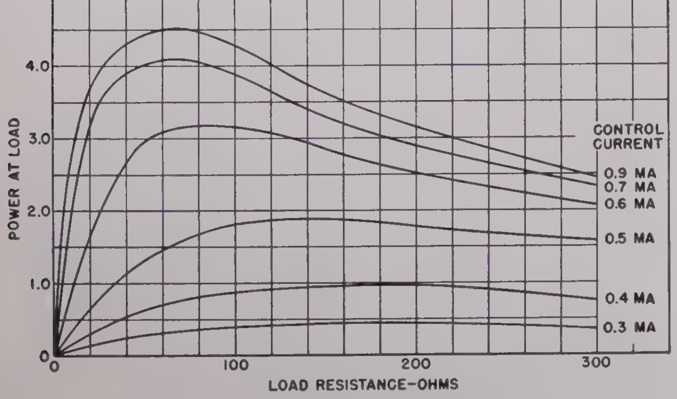

Figure 6. Load power curves

A large number of current transductors rated at 2,000 d-c amperes are in service. The metering circuit is 115 volts, 60 cycles per second, and one ampere at full load. The accuracy is of the order of ±2 per cent at full load. Current transductors are available with current ratings from 1,000 to 100,000 d-c amperes.

The current transductor has several advantages over the conventional shunt. The hazard of shunt leads running from the bus to the instruments is eliminated. The cost of the leads is decreased since small conventional control cable wires can be used instead of specially insulated 1,500-volt wires which must be given special treatment when passing through terminal blocks and onto swinging panels.

The necessity for special calibration of each instrument with its leads is also eliminated. In the case of the 2,000-ampere current transductor, the addition of 20 ohms resistance in the metering circuit decreases the alternating current by only 0.5 per cent. Also, a variation of ±10 per cent in the a-c supply voltage causes only ±2 per cent change in the alternating current.

The Rectomatic battery charger is an automatic self-regulating Rectox rectifier. The charging rate is automatically varied by means of a saturable reactor, and is dependent upon the requirements of the battery. The operation can be understood by referring to Figure 10.

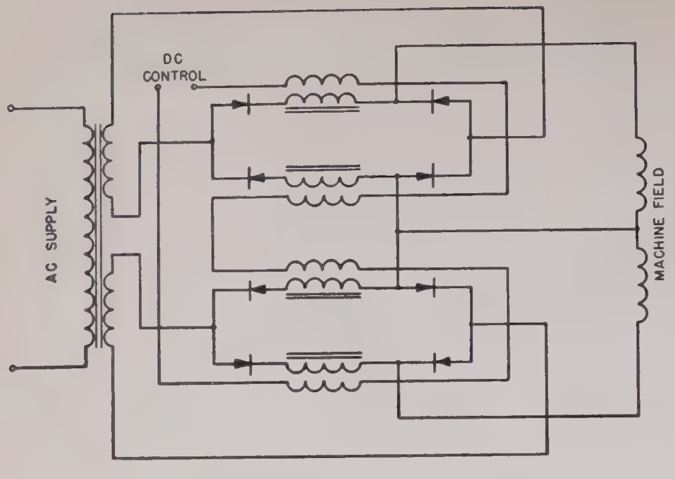

Figure 8. **Balanced magnetic amplifier**

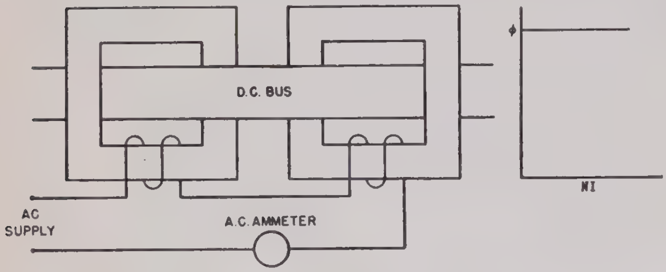

Figure 9. **Current transductor and ideal magnetization curve**

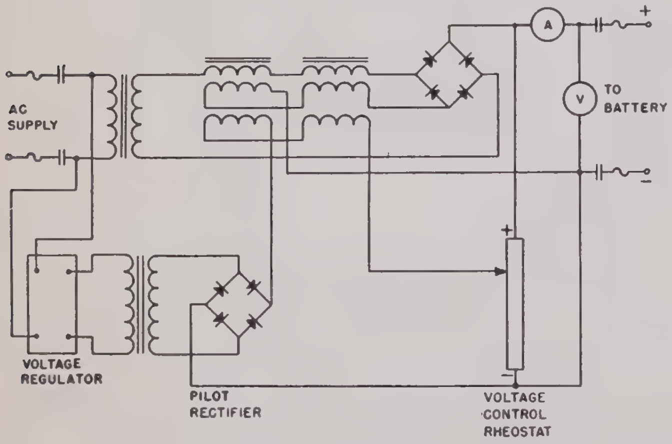

Figure 10. **Self-regulating battery charger**

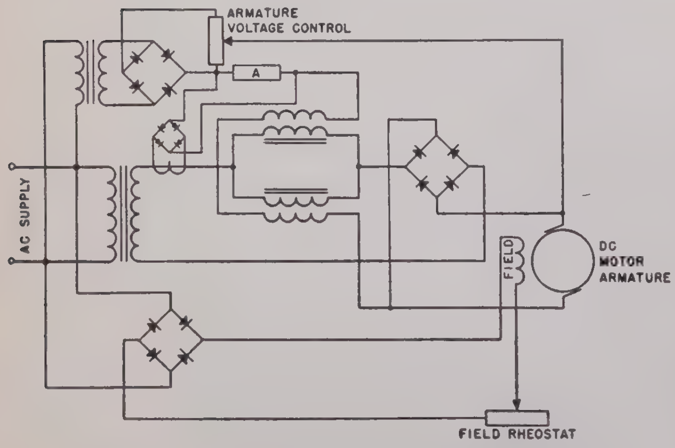

Figure 11. **Adjustable-speed d-c motor drive**

A portion of the battery terminal voltage taken from the voltage-control rheostat is connected opposing the reference voltage produced by a voltage regulator and pilot rectifier. The voltage difference causes a current to flow in the control winding of the saturable reactor. There is also a feedback winding which carries a current proportional to the charging current. If the battery terminal voltage drops below normal, the current through the control winding increases, decreasing the reactance of the a-c windings, and increasing the charging current.

In operation it will maintain a battery at its correct voltage, 2.15 volts per cell, within approximately ±1 per cent under any condition of load within its rating at normal ambient temperatures. These limits are consistent with limits specified by battery manufacturers. The charger will hold the battery within these limits with a ±5 per cent variation in supply voltage.

Magnetic-amplifier control can be used to obtain a wide range of speed of a d-c motor supplied from an a-c source. The circuit is shown in Figure 11. The magnetic-amplifier parallel-connected a-c windings are in series with the motor armature through the load rectifier. A pattern voltage is obtained at the armature voltage control rheostat which is bucked against the terminal voltage of the motor through a d-c control winding on the magnetic amplifier. *IR* drop compensation is provided by resistor *A* in conjunction with a current transformer in the a-c supply circuit. The device is essentially a modified voltage regulator which maintains constant back electromotive force in the motor and maintains constant speed for a given setting of the armature voltage control rheostat. Above the base speed of the motor, speed control is obtained with the motor field rheostat.

In the paper, textile, rubber, and steel industries many core-type reels are required to wind the material which is made along the processing line. The reel drive motor is required to hold constant horsepower as adjusted by a regulator working on the motor shunt field. The magnetic amplifier is ideally suited to do this regulating job as it offers the features of economy and simplicity.

Looking at the circuit of Figure 12, the operation of a paper-mill magnetic-amplifier reel control may be described as follows. The reel motor receives its power from the same adjustable-voltage bus that supplies the entire processing machine. The voltage at the bus is proportional to the speed of the material being processed. The motor shunt field is excited from two sources. The exciter bus supplies the minimum motor field as adjusted by resistor *B*. The motor shunt field can be strengthened only by the magnetic amplifier, which is of the self-saturating type using rectifiers in series with each of the parallel connected a-c windings. Additional feedback is obtained by using feedback windings in series with the motor field. The current in the bias (pattern) winding is adjustable over a range by rheostat *C*. The voltage drop across resistor *A* in the motor armature circuit is applied to the control winding of the magnetic amplifier. The magnetic amplifier functions to hold the reel motor armature current constant as the reel diameter increases from empty core to full roll.

Cut type *C* Hipersil alloy cores are used in the magnetic amplifier. It is true that the air gap at the butt joints of

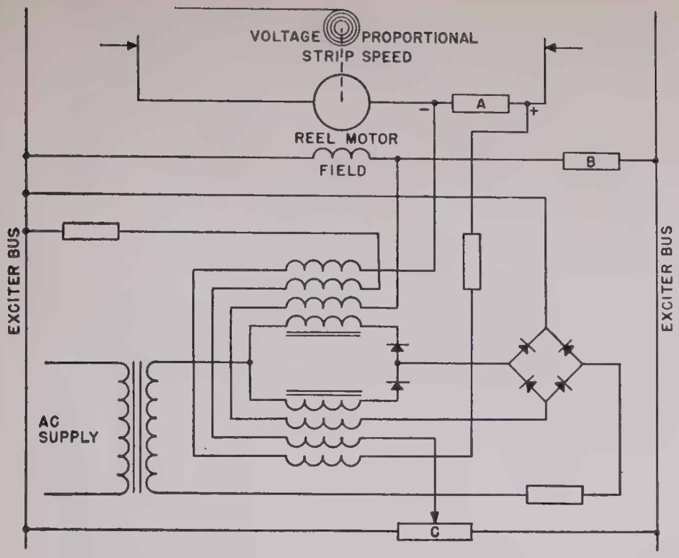

Figure 12. Magnetic-amplifier paper-mill drive control

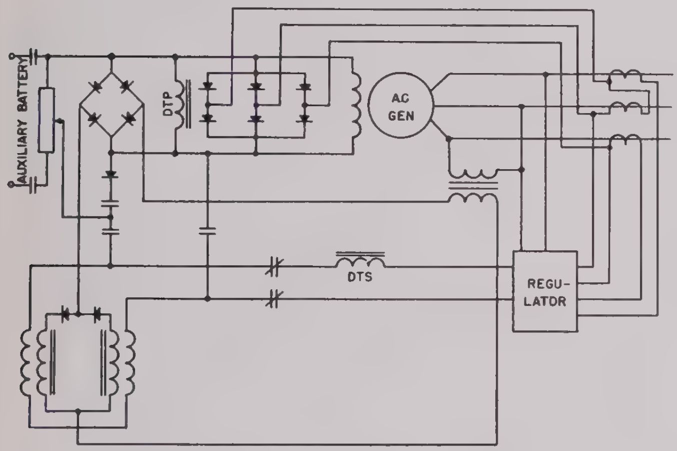

Figure 13. Static exciter and regulator for 60-kw a-c generator

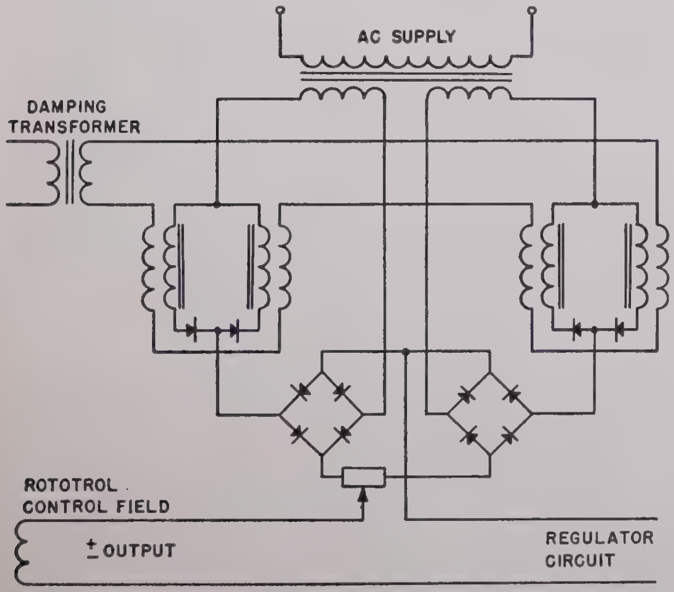

Figure 14. Magnetic amplifier for reducing the size of a damping transformer

small type *C* cores causes poor amplifier operation. However, in the larger sizes the air gap is small in comparison with the length of the flux path and their use results in a large reduction in amplifier cost.

A static exciter and voltage regulator using a magnetic amplifier is illustrated by the schematic diagram of Figure 13. This regulating scheme can be used with a 60-kw a-c generator and may possibly be used with larger units.

For starting, the contacts indicated as normally closed would be open, and the normally open contacts would be closed. Initially, a small current is supplied to the machine field from the auxiliary battery supply. This current also passes through the control windings on the magnetic amplifier so that the full voltage available at the transformer connected to the a-c generator terminals is applied to the full-wave bridge rectifier in the field circuit of the machine. As soon as the terminal voltage begins to rise the machine field is supplied from this circuit. The auxiliary battery supply is needed only to supply a small initial field current. After the generator voltage reaches a predetermined value, the control may be switched to the static regulator circuit which varies the amount of control current in the magnetic amplifier. Under load conditions part of the machine excitation is supplied by the current transformers in the a-c generator leads through a 3-phase full-wave rectifier.

Figure 14 illustrates the use of a magnetic amplifier in a completely different capacity in the regulating circuits of large a-c turbogenerators. The amplifier is used to reduce the size of the damping transformer. Since the series impedance allowable in the regulating circuit is very small, an extremely large damping transformer would be required. However, by using the magnetic amplifier as an impedance-matching device, it is possible to use a normal-sized damping transformer. The amplifier is of the balanced-bridge type with reversible polarity output.

Magnetic amplifiers have been used as photoelectric-cell amplifiers, replacing the often erratic sensitive relays normally used with photoelectric cells. The amplifier can be designed to have a snap-action operation similar to a relay, or it can have an output proportional to the amount of light.

A 2-phase motor can be controlled by a magnetic amplifier to form a tubeless position servomechanism having no sliding contacts. Magnetic amplifiers have been used in many cases to replace sensitive relays. Snap-action operation is obtained by using feedback windings in addition to simplified self-saturation. Sufficient feedback is added to produce instability and a small change in the d-c signal causes the output to change from minimum to maximum.

The frequency of a d-c to a-c motor-generator set can be regulated by a magnetic amplifier. The magnetic amplifier varies the field on the d-c motor in response to signals from a frequency sensitive circuit supplied by generator output.

Although this is only a small number of the many magnetic amplifier applications, it is sufficient to indicate the versatility of the device. However, magnetic amplifiers should not be considered as a cure-all for control and regulating problems. Each application has its own particular requirements, and the magnetic amplifier should be considered along with other possible schemes in determining the best equipment for the job.

Magnetic Cores of Thin Tape Insulated by Cataphoresis

H. L. B. GOULD

High quality cores of thin magnetic tape are being produced commercially. The cores are insulated by a cataphoresis process. The cores are compact rigid structures and have individual turns of tape less than four mils thick which are effectively insulated from each other.

SPIRALLY-WOUND insulated magnetic cores of thin tape play an important role in modern communication systems. In the telephone plant, high-frequency transformers are required in connection with the simultaneous transmission of a large number of messages over a single circuit. In radar, transformers developing high-power microsecond pulses having large components of energy at high frequencies are used extensively.[1] The trend toward high frequencies forced a reduction in the thickness of core laminations. This was necessary to maintain a high effective permeability and low core loss at the operating frequency. Of course, each lamination must be effectively protected against interlaminar welding during the final heat treatment that is required by all high permeability materials to develop their magnetic properties. This welding, unless prevented, permits eddy currents and sets up mechanical stresses which may impair magnetic properties.

The early development of Permalloys,[2] Perminvars, and other magnetic alloys provided a wide range of magnetic characteristics, and the improvement in rolling technique (use of multiple-roll mills with small work rolls) permits rolling these materials into extremely thin sheets without materially impairing their ultimate magnetic properties. Not until the outbreak of World War II, however, was a process for fabricating cores developed that kept pace with these advances.

For low-frequency applications cores usually consist of stacks of punched laminations. These laminations are insulated by dipping them or by spraying them with an inorganic material before heat treatment to prevent interlaminar welding. In some cases they are insulated with shellac or varnish just before stacking into cores. These are economical and practical procedures as long as the material can be handled easily and it is thick enough to mask the effect of heavy insulation on the packing factor of the core. For high-frequency applications the problem of insulating and stacking a large number of thin laminations becomes prohibitively costly. It is avoided by insulating magnetic tape of the desired width and thickness continuously and winding it into a core in one operation.

To obtain high quality cores, strict precautions must be taken in the fabricating process; that is, all the factors that have an influence on the quality of the product must be controlled closely. The magnetic tape that goes into the core must be suitable. The insulation must be very thin and uniform with effective insulating quality during heat treatment and in service. The core must be uniformly wound, closely packed, and sufficiently rigid to withstand normal handling.

The formation of a satisfactory insulating film on thin magnetic tape is simplified if certain precautions are taken in the manufacture of the tape. The finished tape should be straight and of uniform width and thickness. The surface should be smooth and free of scale, flakes of metal, and foreign material. The cross section should be rectangular; the edges free of burrs, nicks, and ripples. The strength and ductility of the tape should be uniformly high throughout. Scale and flakes of metal are minimized by machining the rolled billets early in the tape manufacturing process. Tape with uniform thickness is obtained by carefully rolling the tape in wide sections and then slitting it. Uniform width, straightness, freedom from burrs, nicks, and ripples are controlled by the final slitting operation. Sharpness of cutters and proper adjustment of slitting machines are of prime importance.

Burr is the worst hazard in thin tape core fabrication. This cuts through the thin layer of insulation and makes metallic contact between adjacent turns of tape in the core. It may, in some cases, be even greater in height than the thickness of the tape itself. It can be removed from the tape with deburring knives or grinding wheels, or it can be flattened with a light pass through a rolling mill.

Oil and other foreign material are removed by wiping the tape after it is passed through a bath of carbon tetrachloride or acetone. In this operation short strips of tape are spot-welded together. At a joint, the tape is overlapped to form a straight strip. The overlaps are spot welded along their ends. The tape is then wound under light tension on a supply spool.

METHODS OF INSULATION

Several methods for continuously insulating tape while winding it into cores have been investigated as follows:

1. Tape with a slightly oily surface is drawn through dry insulating powder to pick up a thin layer of insulation.

Full text of paper **50-101,** "Magnetic Cores of Thin Tape Insulated by Cataphoresis," recommended by the AIEE Committee on Special Communication Applications and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 30–February 3, 1950. Not scheduled for publication in AIEE *Transactions*.

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2. Tape is drawn past nozzles spraying a suspension of insulating powder.

3. Tape is drawn through agitated liquid suspension and air-dried.

4. Tape is drawn through a chamber in which dry powder insulation is dispersed in an air stream and allowed to settle on the tape.

5. Tape is drawn through a colloidal suspension of insulating particles. An electric potential is supplied to deposit an insulating layer.

Varying degrees of success have been obtained with all five methods. Method *1* is not adaptable to thin tape insulation because of a lack of control and the unevenness of the coating obtained. Method *2* is not satisfactory because of messiness and difficulty in reproducing a smooth coating. Method *3* is used on thicker tape materials, but the uniformity and thinness of coating are too hard to control for use on thin tape. Method *4* is very slow, and the particles are not easily dispersed. Method *5*, cataphoresis, is most adaptable for thin tape insulation. A thin uniform layer of insulation is obtained, and its thickness is controllable.

Cataphoresis is the deposition of charged colloidal particles under the influence of an electric field.[3] The particles in suspension are charged by the adsorption of an ionic double layer, and their movement can be compared to that of ions carrying a current in a solution. The colloidal particles give up their charge at the electrode and are deposited in a thin film. The adherence of this film is due to close contact with the surface of the magnetic tape and to close nesting of particles arriving after the first layers have been deposited. The rate of deposition, and consequently the thickness of the film, is practically a linear function of time and is proportional to the applied voltage. Deposits obtained from dilute suspensions are more uniform than those obtained from more concentrated suspensions. The prepared suspension offers a relatively easy method of keeping extremely fine particles in a dispersed state.

PREPARATION OF COLLOIDAL SUSPENSION

Commercially, insulation powders are available only in sizes which are large compared to dimensions of the magnetic sheet to be insulated. One-half mil powder is about as fine as can be obtained readily. Actually the particles in such commercial lots range from these coarse or specified sizes down to extremely fine sizes. Thin tape, one mil thick and less, requires insulating films on each surface as thin as one-tenth mil to produce efficient core structures. Considering the fact that each film is made up of a number of

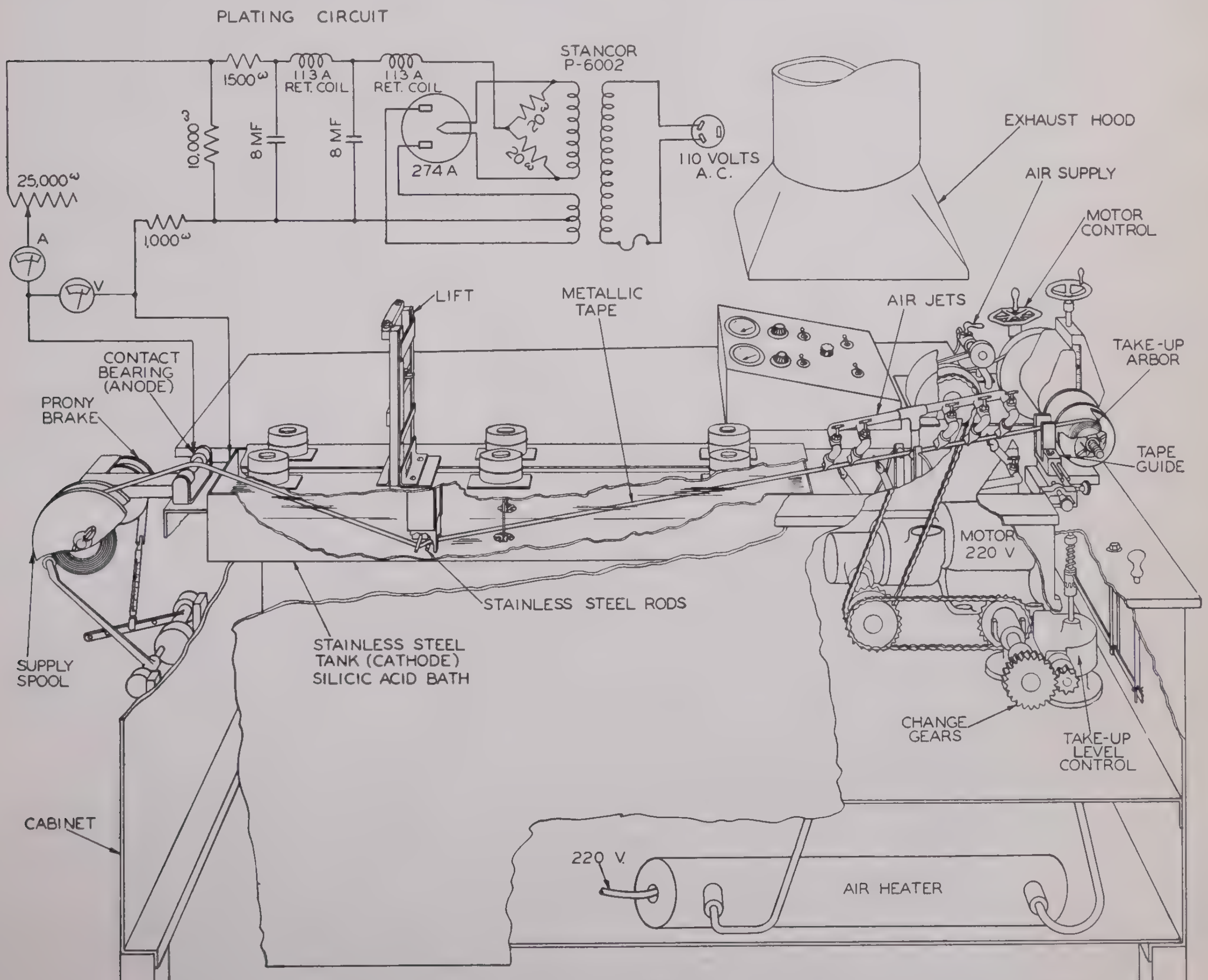

Figure 1. Perspective view of cataphoresis insulating machine for thin tape cores with a schematic drawing of the plating circuit

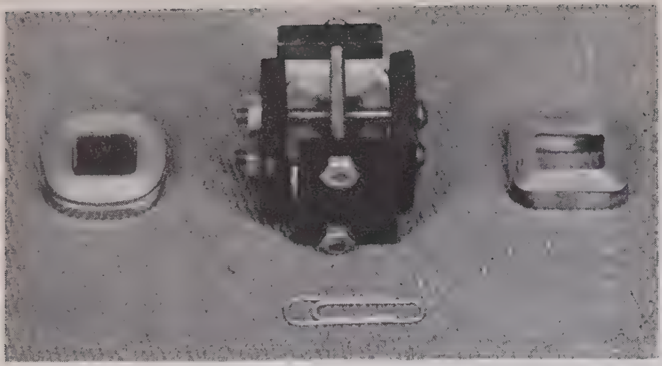

Figure 2. Three steps in the fabrication of rectangular thin tape cores—left to right, wound core, core in clamps, and annealed core

layers of insulating particles, the desired particle diameter is thus placed in the region of 1/50 of a mil (one-half micron). In lieu of other methods, the desired fineness is obtained by ball-milling commercial powders in a liquid and allowing the coarser particles to settle, leaving fine particles in suspension.

A number of suspensions of refractory powders have been investigated such as magnesium oxide, titanium oxide, levigated alumina, quartz powder, and silicic acid, each dispersed in methyl alcohol, carbon tetrachloride, trichlorethylene, or in acetone. Silicic acid in acetone was selected since it produced the most concentrated suspension and gave the greatest rate of deposition. The silicic acid suspension is prepared by grinding dry silicic acid (a white powder, H_2SiO_3, Eimer and Amend chemically pure grade) and acetone (United States Pharmacopeia) in an Abbé mill. After milling, the mixture is allowed to settle and the supernatant liquid is then poured off, ready for use. A suspension prepared in this manner can be kept indefinitely as the particles that settle out over a long period of time can be returned quickly to the dispersed state by simple agitation.

INSULATING EQUIPMENT

The apparatus shown in Figure 1 is a cataphoresis insulating machine. The tape is ordinarily coated on both surfaces with a one-tenth mil film of silicic acid particles which is effective at temperatures up to 1,000 degrees centigrade in atmospheres generally used for annealing magnetic materials. During heat treatment the silicic acid H_2SiO_3 gives up its water of crystallization and becomes silicon dioxide SiO_2. This coating covers the surface of the tape, prevents welding between adjacent turns during the anneal, effectively insulates each turn in service, and produces a rigid, compact core.

The tape is drawn under tension from the supply spool over a stationary leveling and electric contact bearing, into the tank containing the insulating suspension, under and over two stationary stainless-steel guide rods near the lower center of the tank, out between air jets, through a tape guide, and onto the take-up mandrel. A Prony brake on the supply spool supplies the tension.

The tank is made of stainless steel. It is also an electrode in the cataphoresis process, and, therefore, is electrically insulated from all other parts. The tank is approximately 50 inches long, 8 inches wide, 5 inches deep, and holds about six gallons. Since acetone is a highly volatile and inflammable liquid, it is closely confined. The top of the tank is covered except for an opening running the length of the tank to allow the tape to be inserted. This opening is provided with a hinged cover on either side of a framework that can be raised for insertion of the tape. This framework holds two fixed one-half-inch rods of stainless steel mounted in phenol linen insulators, which guide the tape down to the desired depth in the insulating suspension.

In a continuous process such as winding tape into cores any surface irregularities throughout the length of the tape usually impel the tape to walk either to one side or to the other. The over-all axial height of the core is obviously increased by an amount equal to maximum variation in turn location that occurs during the complete core winding operation. This leads to a reduced packing factor of the core.

Thin tape insulation must be dried before it is wound into cores since moist insulation squeezes out between turns under the pressure exerted by the tension on the tape. To shorten the time required for the drying operation, heated air is directed at the tape after it leaves the tank. In addition to evaporating the acetone, the drying jets regulate and redistribute any loose suspension of silicic acid.

The tape guide consists of two vertical chromium-plated steel strips mounted on either side of the tape on an adjustable platform just in front of the take-up mandrel. If one of these strips bears lightly on one edge of the tape it checks the tendency of the tape to walk sidewise in that direction.

The take-up mandrel is usually made of cold-rolled steel. Its size and shape determine the inside dimensions of the desired core. Side plates made of flat steel disks are placed on either side of the mandrel with about six mils clearance for the tape. The diameter of these disks should be slightly greater than the core to be wound. The take-up automatically holds the tape at the proper level with respect to the air jets as the core is wound. Power for the take-up is furnished by a variable-speed drive with speed control manufactured by the Master Electric Company. Six propeller agitators are mounted on the tank to stir up the suspension at intervals and before use.

The plating current is supplied by the circuit shown in the schematic drawing (Figure 1). Its high resistance prevents sparking should the electrodes touch each other in the bath. The current is adjustable in order to regulate the thickness of coating on various widths of tape. The maximum current is limited to approximately 50 milliamperes. An average value used with one-half-inch tape is 20 milliamperes.

INSULATING PROCEDURE

The filled supply spool is mounted on the Prony brake shaft. The tank is filled to about one inch from the top with prepared silicic acid suspension. The framework is raised to expose the submersible guide rods above the tank. The tape is threaded under and over the rods, out between the air jets, through the tape guide, and over the mandrel on the take-up. The frame is then lowered and secured in its normal position in the tank. The tape tension is measured by pulling the tape slowly through the bath by hand using a spring balance. The tension is regulated by adjusting the setting of the Prony brake. The tension is not critical but should be great enough to produce a compact core, to obtain proper running of the tape, and to insure the proper action of the guide rods. For one-mil by one-half-inch tape which has a tensile strength of approximately 50 pounds, three to five pounds tension is sufficient.

The periphery of the mandrel is covered with a layer of paper approximately four mils thick that carbonizes during the subsequent heat treatment, thus freeing the core. The tape initially is secured to the paper with a tab of Cellophane tape, and slightly more than one complete turn is wound on tightly by hand. Then the mandrel is clamped securely between the side plates on the take-up shaft. The tape guide is adjusted to one-mil clearance on either side of the tape, and the take-up is set at the proper height. Before starting, the air, heated to 150 degrees Fahrenheit, is turned on to warm up the air jets, and a positive potential of about 25 volts is applied to the tape.

The level of the bath should be maintained by the addition of acetone from time to time. During prolonged operation, concentrated suspension is added at intervals to maintain adequate insulation. This may be judged by comparing the cloudy appearance of a sample in a beaker with a standard. The fire hazard caused by the inflammability of acetone is minimized by enclosing the bath and removing the vapors rapidly through an exhaust hood.

The thickness of insulation is controlled by the plating current, length of tape in the bath, concentration of suspension, air jets, and speed. The uniformity is controlled by the surface condition of the tape, tension, and air jets. Plating current, air jets, and speed should be regulated to produce, effectively, a one-tenth mil coating of insulation on each surface of the tape. This is measured by observing the pile up of trial cores. This thickness of insulation (greyish white in appearance) has been found to give adequate protection during heat treatment and to prevent eddy currents in service.

A d-c ohmmeter is a useful tool in checking the insulation of thin tape cores. It is used to indicate the quality of insulation at the time the core is wound. The resistance of the unannealed core is measured from the inside turn to the outside turn or taken in parts by a probe test across the edges. The value measured should approach the value of the resistance of the uncoiled tape. Low values indicate that the insulation will be faulty after heat treatment. In most cases an annealed core is satisfactory if its resistance is distributed evenly through the core and is more than ten per cent of the total perfectly insulated value.

In general, the thinner the tape the more difficult it is to wind wide cores. This is due to irregularities in the tape and to the higher tension required to form a tight core. Experience has shown that below two mils using commercially rolled material, the ratio of width to thickness should be less than 750 to 1 for best results.

Failure to operate the machine properly results in the production of inferior cores. If the coating is too light the insulation is insufficient to prevent welding during the anneal. If the coating is too heavy, particularly at the edges, either the insulation tends to flake off leaving bared spots that weld or the packing factor of the core is lowered materially.

THIN TAPE CORES

Thin tape cores, broadly speaking, are of two general types or shapes, toroidal and rectangular. Toroidal cores after fabrication usually are prevented from unwinding until after heat treatment by a single turn of nickel wire wound around the periphery. Insulation is removed from the beginning and end of the core to stimulate welding down of the loose ends during the anneal. Unless this is done the ends must be cemented to the core after heat treatment. Rectangular cores after winding are held temporarily with Cellophane tape, and in place of the nickel wire cold-rolled steel plates are used to compress the sides of the cores where they tend to bow out (Figure 2).

All thin tape cores of high permeability material are given a final heat treatment after fabrication to relieve mechanical strains due to processing. To maintain physical dimensions, the cores, clamps, and mandrels are annealed as a unit. Although high-permeability cores are

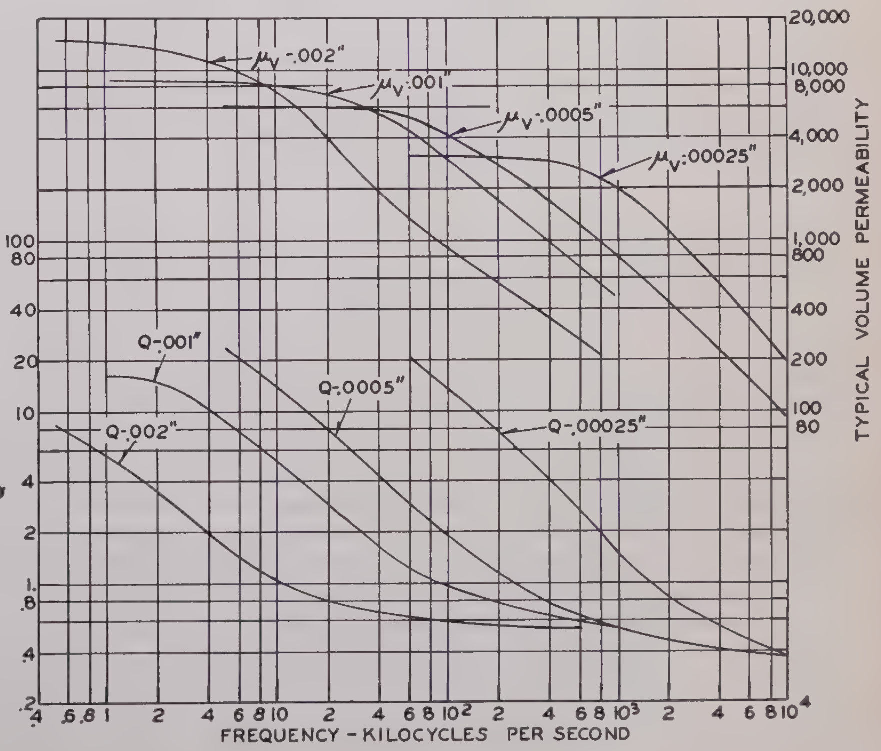

Figure 3. Typical variations with frequency of the volume permeability and *Q* of 4-79 molybdenum Permalloy thin tape cores

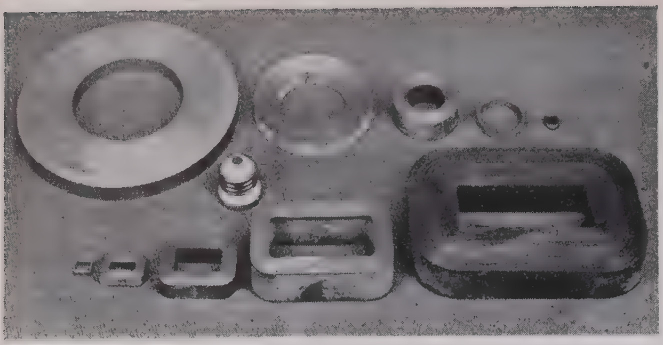

Figure 4. Miscellaneous sizes of toroidal and rectangular thin tape cores; one-inch plug fuse shows scale

extremely sensitive to strain, they retain their magnetic quality so long as they are not under stress and their mechanical tightness is maintained. Two adjacent turns in a tight core may be compared to two pieces of sand paper that resist sliding past one another but can be easily pulled apart. If care is taken to avoid breaking the brittle bond between turns, the cores will withstand normal handling and require no extra strengthening prior to the coil-winding operation. In cases where impregnation is desirable, the compactness of the core minimizes the straining effects of impregnating compounds.

In providing air gaps, the annealed core is clamped at the cut with brass clamps or similar arrangement and slowly cut with a wet rubber bonded cut-off wheel. The metallic bond formed between laminations during cutting is broken by flexing the core or by directing high-pressure air at the cut surface. The insulation having fused slightly during heat treatment is not dislodged unduly by this operation.

MAGNETIC QUALITY

Since the magnetic properties of cores depend upon the characteristics and the quantity of magnetic material in them, a certain degradation in the properties of thin tape cores is expected for the following reasons. In the process of manufacture a microscopically thin layer of inferior magnetic material is formed on the surfaces of laminations and tape. Unfortunately, it is not removed in the final heat treatment. If the tape is thin, an appreciable degradation is observed in the quality of the cores. For instance, the permeability and coercive force of 1-mil 4-79 molybdenum Permalloy tape cores compared with those of 6-mil tape cores may be approximately 25 per cent lower and higher, respectively. In addition, the quantity of magnetic material is lower in thin tape cores because the amount of tape that can be wound into a core is determined by the ratio of tape thickness to insulation thickness. Accordingly, thin tape cores are fabricated with the interlaminar insulation as thin as possible consistent with insulating efficiency. Typical packing factors obtained with this process are as follows: 2-mil tape, 90 per cent; 1-mil tape, 80 per cent; and one-quarter mil tape, 50 per cent. Figure 3 shows typical volume or gross core area permeability and Q of 2-, 1-, 1/2-, and 1/4-mil tape cores as a function of frequency.

APPLICATIONS

This method of insulation immediately proved its usefulness, particularly in applications where high quality cores are at a premium. It has been extensively used for cores in nonlinear coils, pulse transformers, and magnetrostrictive elements. Magnetrostrictive elements have been made from closely-wound impregnated cores of 2-mil tape that approach very closely the response of the solid material. Toroidal and rectangular cores for a few applications are shown in Figure 4. Weights range from several pounds to a fraction of an ounce.

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Ultrasonic Detector Car Locates Defects in Rails

"Silent sound" has been successfully harnessed to the task of locating rail defects at joints, crossings, switch points, and other complicated track structure. The new equipment, manufactured by the Sperry Rail Service, a division of Sperry Products, Inc., Danbury, Conn., is identified as an ultrasonic detector car. It locates defects in rails by transmission of pulsed ultrasonic vibrations of a frequency far above the audible range through a quartz-crystal searching unit and indicates visually the reflections from the defects.

The car is a gasoline-propelled unit weighing approximately 500 pounds with the detection equipment and operator's seat located on a swinging cantilever which enables the operator to reach either rail. An electric generator furnishes power for testing and for an auxiliary drive. Joint fingers, which are tripped by the joint bars, stop the car in the correct position for testing for defects in rails.

The operator watches the cathode-ray screen on the detection equipment and makes a complete pass forward and backward over the rail joint with the searching unit touching the running surface. If the beam pattern indicates that the rail is sound, he pushes a button and the car moves ahead. While the car is moving, the operator switches over to the opposite rail and is ready to test. When a joint finger engages the next joint bar, the control circuit is tripped and the car is stopped automatically at the correct position for test.

The new ultrasonic detection equipment was developed from the ultrasonic reflectoscope, a nondestructive testing instrument used in industry for testing metal and metal products.

Large Electronic D-C Motor Drives in Industry

M. M. MORACK
MEMBER AIEE

THE TREND IN INDUSTRY is toward the wider use of adjustable-speed drives. An endless list of processes and conditions suggest the reasons for this trend. A piece of material—it may be a strip of steel or a web of cloth or paper—may pass in continuous flow from one machine to another with each machine doing some work in the material. There will be different kinds of materials, changes in physical properties, and changes in size during processing, all of which will require adjustable speed if processing is to be uniform and if high quality is to be maintained.

Engineers have long been searching for a better adjustable-speed drive. The large electronic d-c motor drive, in ratings of 100 to 10,000 horsepower providing high efficiency, wide range of speed adjustment, and lower installation costs, offers a new approach to this age-old problem.

D-c motors were first in the field of power utilization devices, but the invention of the induction motor and the many advantages of a-c distribution have led to the wide application of a-c instead of d-c motors. With the rapid growth in a-c power distribution systems the trend was toward the universal use of a-c machines. This trend reached its peak with such inventions as the Cramer and Scherbius adjustable-speed drives, brush shifting motors, and the like.

In recent years industry has slowly returned to the use of d-c motors for many applications. It is now apparent that adjustable-speed drives are necessary to obtain the high standard of performance required by many industrial operations. D-c motors operating from a constant-potential supply inherently possess, according to their type and design, a greater variety of speed torque characteristics and a greater ease of control than any other type of motor, but their use is limited because of the prevalence of a-c power. When an a-c network is the only power supply, some form of converter is required to furnish power for the d-c adjustable-speed drive.

Adjustable-voltage rectifiers offer a new engineering and economic approach to the adjustable-speed problem. When a rectifier and a d-c motor are considered as a unit, the motor speed may be adjusted by controlling the armature voltage by phase-controlling the rectifier. When needed, an additional speed range may be provided by field control.

Single-phase rectifiers for armature voltage control of d-c motors were first used many years ago, and have had wide application in the smaller ratings. Their size was limited because of economic factors. Recent developments in power circuits and larger rectifying devices, however, have overcome the previous difficulties until now the electronically controlled motor systems are being used in applications requiring many hundreds of horsepower. The large drives incorporate these desirable operating features:

1. Wide, stepless speed range.
2. Smooth acceleration by current limit control.
3. Automatic speed regulation at preset speed.
4. Rapid retardation by dynamic braking.

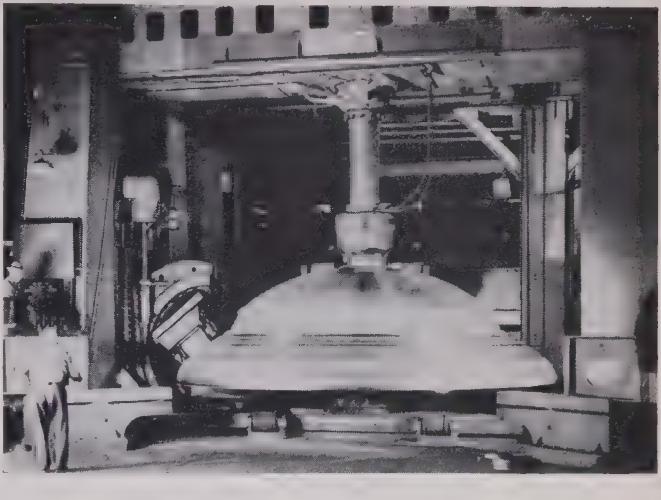

Figure 1. 300-inch hot flanging mill. Main spindle driven by 350-horsepower 550/1,100-rpm electronic d-c motor drive

The new double-way phase-controlled sealed ignitron rectifier is directly connected to a 460-volt 3-phase power supply and is used to furnish adjustable voltage to a 550-volt d-c motor. This eliminates the economic disadvantage arising from the use of the usual rectifier anode transformer. Another advantage inherent in the double-way power circuit is that the output wave form is that of a controlled 6-phase rectifier which allows the use of 550-volt motors approximating conventional design. The use of rectifiers, noted for high efficiency and low no-load losses, with 550-volt d-c motors gives high over-all efficiency. In addition, rectifiers are factory-packaged units which result in low installed cost.

Although the large electronic d-c motor drive is still in its infancy, many thousands of horsepower are already installed for operating printing presses, fan drives, and metal working mills. Figure 1 shows a 300-inch flanging mill where the electronic drive provides for the complete control functions including starting, jogging, low-speed running, acceleration, and emergency stopping. Usually phase control is used only for low-speed operation and the motor field is weakened above base speed to obtain wide speed range, high efficiency, and good power factor.

Heavy industry, in particular, is turning to this new electronic tool which gives an ease of control and a higher efficiency unmatched by older forms of conversion equipment.

Digest of paper **50-31**, "Large Electronic D-C Motor Drives in Industry," recommended by the AIEE Committee on Electronic Power Converters and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N.Y., January 30–February 3, 1950. Not scheduled for publication in AIEE *Transactions*.

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Electrical Essays

Delta Network

Consider the network shown in Figure 1, and the following statements:

1. My reference book on network solution says that a network of three impedances connected in delta can be replaced by an equivalent network of three impedances connected in star. "The star branches are the product of adjacent delta branches divided by the sum of all delta branches." The circuit of Figure 1 cannot be replaced by an equivalent star circuit.

True or *false?*

2. When this circuit is connected to a source of balanced 3-phase voltage of either positive or negative sequence, it will draw current from each of the three line connections. Should any one line connection be broken, no current will be drawn by the circuit from the other two line connections.

True or *false?*

3. My reference book on symmetrical components says: "The type of unbalance or dissymmetry in the circuit can be represented by an interconnection between the equivalent sequence networks." It illustrates this with many diagrams like the one shown in Figure 2. Therefore, if the circuit of Figure 1 is connected to the three lines of a symmetrical 3-phase system, it can be represented by impedances interconnecting the sequence networks of the system to which it is connected.

True or *false?*

A. A. KRONEBERG (F '48)
(Southern California Edison Company, Los Angeles, Calif.)

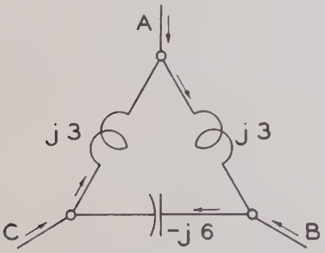


Figure 1

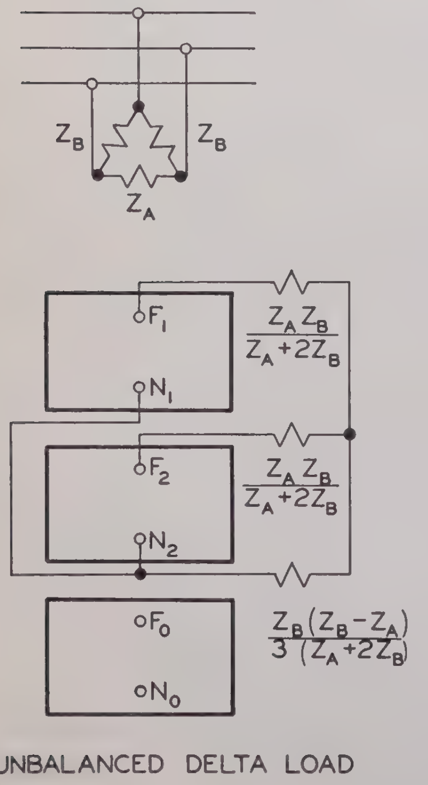

Z_B
Z_B
Z_A
F_1
N_1
$\frac{Z_A Z_B}{Z_A+2Z_B}$
F_2
N_2
$\frac{Z_A Z_B}{Z_A+2Z_B}$
F_0
N_0
$\frac{Z_B(Z_B-Z_A)}{3(Z_A+2Z_B)}$
UNBALANCED DELTA LOAD

Figure 2

Magnetized Iron, Stretched or Swelled?

I admit I was in a huff when I left Bill and Charlie, the physicists, at the Research Laboratory the other day, after they told me that my Electrostatic Space Ship (*EE, Feb '50, p 164; EE, May '50, pp 456–7*) wouldn't work. I was still in a huff as I worked on my next job, a magnetic controller for a motor. But as I watched the switches open and close when I energized and de-energized the magnet coils, it suddenly dawned on me that these here iron armatures which are being pulled hither and yon by the magnetic field are very much like the titanate dielectric of my space ship. They also have two fields **B** and **H** and a volume magnetization density **M**, with

$$\mathbf{B}=\mathbf{H}+4\pi\mathbf{M} \tag{1}$$

just like the equations of Bill and Charlie for the dielectric

$$\mathbf{D}=\mathbf{E}+4\pi\mathbf{P} \tag{2}$$

There sure is a force on these iron armatures, so maybe there will be a force on the titanate which will just ruin my space ship like Bill and Charlie calculate. But why do they have different values for the volume force, so that even though they integrate up to the same ruination of my space ship, they give different stretching forces on the titanate?

I suppose Bill will say that for iron there is an apparent magnetic charge $\rho_m'=-\text{div }\mathbf{M}$, even though there isn't any real magnetic charge no place in nature since always $\rho_m=\frac{1}{4\pi}\text{ div }\mathbf{B}=0$, and that there will be a volume force $\mathbf{f}_B=\rho_m'\mathbf{H}$. Charlie, however, will say that the volume force is $\mathbf{f}_c=(\mathbf{M}\cdot\nabla)\mathbf{H}$.

For a uniformly magnetized iron cylinder in a uniform magnetic field Bill will say there is a tension per square centimeter:

$$T_B=-\frac{1}{8\pi}(H_1^2-H_2^2) \tag{3B}$$

while Charlie will say that the tension per square centimeter is

$$T_C=-\frac{1}{8\pi}(H_1^2-2H_2B_2+H_2^2) \tag{3C}$$

where the subscript 1 refers to the fields normal to the ends outside the end surface, and the subscript 2 refers to the normal fields inside the end surface.

I had an idea. I would show Bill and Charlie that I had no hard feelings, and also show them how to find out which is the right tension, T_B or T_C. I picked up an iron cylinder and a hacksaw, and at lunchtime I rushed over to the Research Laboratory cafeteria, and pushed over to the table beside Bill and Charlie.

Well, it was like I said. Bill claimed T_B, and Charlie T_C. "Now," I said, "I'll settle it. There is a magnet up here, I am told, a cyclotron or something, so big that I can stand between the poles. I'll get in there and place this iron cylinder in the middle parallel to the field. The net force on it will be zero, but there will be a pull on each end trying to pull the ends apart. Then with my hacksaw I'll cut the cylinder across the middle, and measure how much force it takes to keep the two parts from being pulled away from each other by the pull on the ends."

"That's no good!" said Bill, "as soon as you make that saw cut new apparent charges, ρ_m', will appear there, and the force on that new apparent charge will keep the two parts from pulling apart."

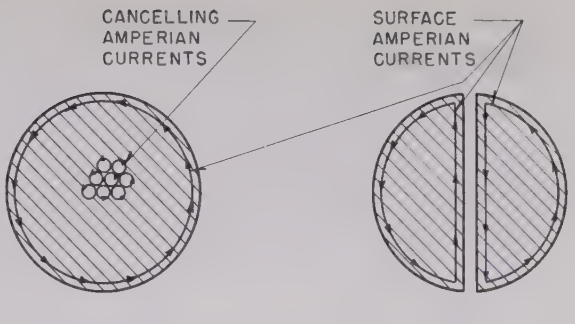
"You're right, it's no good," said Charlie, "but that's because at the new surfaces you produce by the cut, there will be a discontinuity in **H**, and the magnetic dipoles there will now have a pull on them which will keep the two parts from separating."

The fellow next to us began to have a violent coughing spell, choking over his soup. His name was Jack, and I could tell by his looks he was a physicist. "You are all wrong, all of you!" he spluttered. "There is no such thing as magnetic charge, so you can't have unipoles, and if you can't have unipoles, you can't have dipoles. Everybody knows that magnetism in a body is due to little circulating electric currents, the Amperian currents, I. Their density is given by $\mathbf{I}=\text{curl } \mathbf{M}=1/4\pi \text{ curl } \mathbf{B}$, since $\text{curl } \mathbf{H}=0$. Inside the cylinder these Amperian currents will overlap and cancel out giving $\mathbf{I}=0$ as you can see since $\text{curl } \mathbf{B}=0$ there. But at the cylindrical surface the parallel component of B has a discontinuity. The Amperian currents don't cancel out there but form a surface current sheet of magnitude $I_s=-\frac{1}{4\pi}(B_1-B_2)$, as shown in Figure 1*A*. The mean field this current sheet is in is $\frac{1}{2}(B_1+B_2)$. Therefore there will be a radial force or tension on the side walls given by

$$T_J=-\frac{1}{4\pi}(B_1-B_2)\frac{1}{2}(B_1+B_2)=-\frac{1}{8\pi}(B_1^2-B_2^2) \qquad (3J)$$

per square centimeter, tending to swell out the iron cylinder radially."

"Well," said I, "here's a force trying to pull the cylinder apart sideways. Then I'll cut the cylinder in two parts lengthwise." "No good," said Jack, "as soon as you make the cut there will be the same Amperian surface current density, giving the same normal tension force T_J, equation 3*J*, on the new surfaces. (See Figure 1*B*.) The two parts will still be in equilibrium and will not pull apart."



A—Uncut *B—Cut*

Figure 1. Amperian currents in iron cylinder

Well, lunch hour was over, and I rushed back to my job, leaving the three of them arguing at a great rate. Are there as many opinions as there are physicists? Is there an axial tension, T_B, or T_C, or is there a radial tension, T_J? Is a magnetized iron cylinder stretched or swelled? And what kind of forces are these that I can't measure by an experiment?

J. Slepian, Alter Ego

J. SLEPIAN (F '27)
(Westinghouse Research Laboratories, East Pittsburgh, Pa .

Answers to Previous Essays

Force on a Dielectric. The following is the author's answer to a previously published essay of the foregoing title (*EE, May '50, pp 456–7*).

By this time, perhaps, the reader is prepared to believe that no uniquely valid meaning can be given to the notion of the force per unit volume within material bodies, which arises from the action of the local electromagnetic field there. No operational definition of such volume force can be given.

The expectation that such a uniquely definable and observable volume force exists arose during the period when scientists believed that the electrical properties of bodies could be accounted for by assuming that they were made up of charged microscopic particles, which obeyed Newtonian mechanics, and which had acting upon them the Lorentz forces $\mathbf{F}=q(\mathbf{E}+[v\times B])$, and also other nonelectric or mechanical forces which equilibrated the Lorentz forces. However, this expectation of the scientists has failed. In our present-day theories of the structure of matter, the microscopic particles, our electrons and nuclei, do not obey Newtonian mechanics, but quite another, that is, quantum mechanics. Also, the nonelectric, or mechanical, forces on the particles have completely disappeared, at least when we do not deal with energetic nuclear interactions. Hence, there is no theoretical basis for speaking of a volume force in matter arising from the macroscopic Maxwellian electromagnetic field.

However, for macroscopic bodies, we do have Newtonian mechanics, and we are able to determine the mechanical forces exerted upon such bodies by noting the strains in abutting bodies, such as twisted strings or compressed push rods, or the remoter presence of gravitational matter. In fact, the definitions of the electric and magnetic field and electric charge depend upon our capacity to observe and recognize these "purely" mechanical forces.

It has meaning, therefore, to speak of the total force arising from the electromagnetic field acting on a macroscopic or ordinary body which is separated from all other bodies except those which we recognize as purely mechanical in their action, such as pull strings or push rods. The total electric force is then determined by the amount by which the mechanical forces fail to balance according to Newtonian mechanics.

Similarly, we may speak meaningfully of the total electric torque on a macroscopic body, which is separated from all other bodies influencing the electromagnetic field.

Whatever expressions or formulas we may use for the electric force density or torque density in matter, we should expect or require them to integrate to the same total force or torque, namely, the one we observe by mechanical means, for any body in empty space. We see that the various electric force densities used by Bill, Charlie, and the other even more eminent physicists, all integrate to the same total value when applied to the plate structure of Alter Ego's invention. Apparently they are all equally valid in agreeing with what can be observed for total bodies.

Maxwell has given a general method for determining the total electric force on a body by integrating a certain tensor function of the electric and magnetic fields over a surface lying in empty space and enclosing that body. In a later essay the author will show how from Maxwell's tensor, infinitely many valid electric force density formulas may be deduced.

Returning to the essay, our conclusion is that so far as observable phenomena go, both Bill and Charlie are right.

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Unbalanced Load. The following is the author's solution to a previously published essay of the foregoing title (*EE, May '50, p 457*).

In selecting a base for the analysis of the problem, the author notes the voltage drop taking place when the load is connected to the system. From this he deducts

$$\frac{IR}{E}=\frac{R}{Z}=\cos\theta=0.9487=\frac{3}{\sqrt{10}}=3\sin\theta \qquad (1)$$

The author selects the following base:

$E=10$
$I=\sqrt{10}$
$Z=\sqrt{10}$

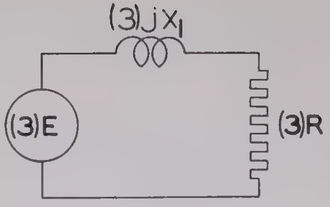
and derives the following:

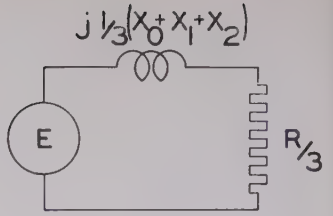
$R=3$
$X_1=1$
$P=3I^2R=90$

An equivalent single-phase circuit is shown in Figure 1.

The electrician reported two-thirds normal power developed in the parallel connection of three resistors and the author notes this as follows:

$P'=60$
$R'=1$
$I'=\sqrt{60}$





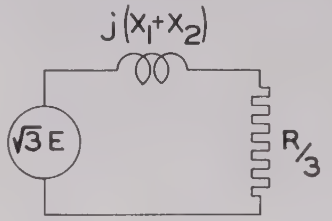


Figure 1 (above, left)

Figure 2 (above, right)

Figure 3 (left)

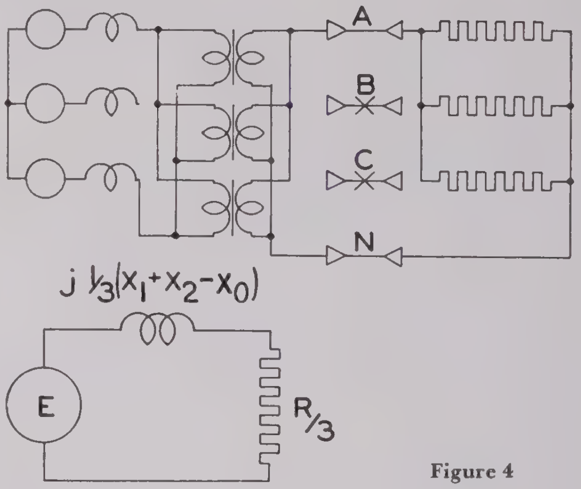


Figure 4

The method of symmetrical components gives the following two formulas for calculating currents in single-phase load connected from line to neutral and from line to line on a 3-phase system:

$$I'=\frac{3E}{\sqrt{(3R')^2+(X_0+X_1+X_2)^2}} \qquad (2)$$

$$I'=\frac{\sqrt{3}E}{\sqrt{(R')^2+(X_1+X_2)^2}} \qquad (3)$$

The equivalent circuits of Figures 2 and 3 corresponding to connections shown in figures of the same number in the essay illustrate the foregoing formulas.

The only unknown in equation 3 is the negative sequence reactance X_2, which can, therefore, be evaluated. Following this, the only remaining unknown in equation 2 is the zero sequence reactance X_0. The two reactances then are

$X_2=1.00$
$X_0=0.45$

Since transformer connections are delta-star, the zero sequence reactance is that of the transformer and the reactance of the system is obtained by subtraction from the positive sequence reactance.

In reply to the electrician's second question, the author suggests the connections of Figure 4, which will produce 87.7 per cent normal heat in the resistors.

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Digests of District Papers at North Eastern District Meeting

These are authors' digests of some of the District papers presented at the AIEE North Eastern District Meeting, Providence, R. I., April 26–28, 1950. These papers are not scheduled for publication in AIEE Transactions or AIEE Proceedings, nor are they available from the Institute.

Density Distribution of Transient Currents in Conductors; *Lucio M. Vallese (Duquesne University, Pittsburgh, Pa.).*

The study of the density distribution of currents in the cross section of conductors is extended to the cases of pulse, exponential decay, and circular-exponential decay forms. For a pulse current of width T_0, $i=I_0[U(t)-U(t-T_0)]$, considering the classical case of a plane surface conductor and current flow parallel to the surface, it is found that the density for $t\leq T_0$ is $\mathfrak{J}(z,\ t)=\dfrac{I_0}{h\sqrt{\pi t}}e^{-z^2/4h^2t}$ where $h=1/\sqrt{\sigma\mu}$, z is the depth measured normally from the surface and I_0 is the amplitude of the total current per unit width of the conductor. At constant depth z and $t\leq T_0$ a peak value of $\mathfrak{J}(z,\ t)$ is reached at $t=z^2/2h^2$, namely $\mathfrak{J}_{\max}=\dfrac{I_0}{z}\sqrt{\dfrac{2}{\pi e}}$. The depth of peak density at $t=T_0$ is assumed as equivalent depth of penetration, obtaining $\delta=\sqrt{\dfrac{2T_0}{\sigma\mu}}$; for copper $\delta\approx 0.166\sqrt{T_0}$ meters. On the other hand, by consideration of the average losses per unit square surface of the conductor from time zero up to T_0, it is found that the depth of equivalent d-c resistance is $\delta'=\sqrt{\dfrac{\pi T_0}{2\sigma\mu}}\approx 0.89\ \delta$.

For an exponential decay pulse $i=I_0e^{-\alpha t}U(t)$ the general expression of the density distribution in the plane penetration case is

$$\mathfrak{J}(z,\ t)=\frac{I_0}{h\sqrt{\pi t}}\epsilon^{-z^2/4h^2t}+\frac{I_0}{2j}\ ke^{-\alpha t}\left\{\epsilon^{jkz}\mathrm{erfc}\times\left(\frac{z}{2h\sqrt{t}}+j\sqrt{\alpha t}\right)-\epsilon^{-jkz}\mathrm{erfc}\left(\frac{z}{2h\sqrt{t}}-j\sqrt{\alpha t}\right)\right\}$$

where $k=\sqrt{\alpha}/h$ (for copper $k=8.5\sqrt{\alpha}m^{-1}$). For large values of α an approximate formula for the depth of penetration may be $\delta=\sqrt{2/\sigma\mu\alpha}$; it may be obtained considering the exponential pulse as equivalent to a rectangular pulse of width $T_0=1/\alpha$. For small values of α it may be of interest to examine the "steady-state" solution, that is, the density distribution of $I_0e^{-\alpha t}$ considered applied from $t=-\infty$. For the plane penetration case $\mathfrak{J}=kI_0\cos(kz)e^{-\alpha t}$ and for the case of a cylindrical conductor with circular cross section $\mathfrak{J}=\mathfrak{J}_0J_0(kr)e^{-\alpha t}$ where $\mathfrak{J}_0$ is the current density at the axis at time zero and J_0 is the Bessel function of first kind, zero order. In both cases the density distribution presents points of zero and inversions of sign, although the total current is unidirectional. In the cylindrical case the ratio of the transient resistance to the d-c resistance per unit length is $R_t/R_0=\left(\dfrac{ka}{2}\right)^2\left\{1+\dfrac{J_0^2(ka)}{J_1^2(ka)}\right\}$ where a is the radius of the conductor and J_1 the Bessel function of first kind, first order. It follows that R_t becomes infinite (and the total current zero, because of the inversions of sign of $\mathfrak{J}$ in the cross section) at the zeros of $J_1(ka)$. The minimum critical radius for copper, however, is $a=0.445/\sqrt{\alpha}$ meters, which, considering that α is small, is very large in respect to values used in practice.

The analysis may be extended similarly to a current $i=I_0e^{-\alpha t}\sin\omega t$, considered applied from $t=-\infty$, when α is small enough. For the plane penetration case it is found $\mathfrak{J}(z,\ t)=\mathfrak{J}_0e^{-k_1z\sin\varphi-\alpha t}\sin\ (\omega t-k_1z\cos\ \varphi)$, where $k_1=\sqrt[4]{\alpha^2+\omega^2}/h$, $2\varphi=\tan^{-1}\left(\dfrac{\omega}{\alpha}\right)$. For the equivalent depth of penetration it is obtained $\delta=1/k_1\sin\varphi$.

Computer Experience in Extending Tube Life; *Edwin S. Rich (Massachusetts Institute of Technology, Cambridge, Mass.).*

An effective improvement in the life and reliability of receiving-type vacuum tubes has been obtained on the Whirlwind Computer Project at the Massachusetts Institute of Technology by applying a combination of three principles: using only those tubes which have been determined to have a good life expectancy; avoiding operating procedures that are detrimental to tube life; and choosing circuit designs which, as far as possible, are insensitive to changes in tube characteristics.

Procedures for tube selection have been worked out along two lines; the first to predict whether cathode-interface deterioration will occur, and the second to detect tubes with mechanical weaknesses or improper processing. The formation of an interface, which produces the effect of a parallel resistance-capacitance network in the cathode circuit of a tube, was first observed on the project in early 1948; it is the most serious type of deterioration that has been encountered. It has been found that a 500-hour life test at an elevated cathode temperature on a sample of tubes from a given production lot is a satisfactory method for determining whether tubes from that lot will remain essentially free of interface deterioration for several thousand hours of normal operation. Before final selection of tubes is made, each tube is preburned for about 100 hours. This tends to stabilize plate current as well as to precipitate failures that would result from mechanical defects or gas within the tube.

To extend the life of the tubes selected for use, cautious operational procedures are observed. In particular, the tubes are not left for extended periods with heater voltage alone applied, since this condition promotes the formation of cathode interface. Since the tubes must be turned on and off daily, heater voltage is applied and removed gradually over automatically controlled 5-minute cycles to reduce thermal shock to the filaments.

As a final consideration, wide operating margins have been provided in the circuit designs, both with regard to tube performance and to dissipation ratings. Records of the performance of selected tubes over a period of more than 10,000 hours show that they have a life expectancy considerably greater than would be predicted by most design engineers.

Digital Computers in Control Systems; *C. Robert Wieser (Massachusetts Institute of Technology, Cambridge, Mass.).*

Contrary to the optimistic implications of some popular reporting, large-scale digital computers are still in the development stage, and their application is virtually unexplored. However, within the next two decades computers probably will be applied to automatic control systems.

Two types of control systems can use a high-speed digital computer. In one type, control consists almost entirely of information processing; the logic is simple, the procedures are repetitive, and the number of quantities controlled is very large. Examples are: control of the circulation of a weekly magazine with several million subscribers; keeping insurance records; inventory control in a large company; and military logistics.

The second type of problem, which is based on much more complex logic, is control of several interdependent quantities. An example is automatic control of air traffic, which would require computation of control instructions for up to 100 aircraft around a busy airport. Proper instructions for each aircraft would depend on the traffic rules and the behavior of the other aircraft. By scanning information very rapidly the computer should have a virtually continuous grasp of the behavior of the whole system.

A gigantic task of computer development lies ahead, particularly in improvement of reliability. Better vacuum tubes and components, as well as the invention of new circuit elements like the transistor, are needed from the electronics industry.

The greatest impact of the computer on engineering is the expansion of the scope of automatic control. The computer will make it possible to control automatically not merely a few quantities but a dynamic situation.

New Developments in Pulsed Circuit Test Equipment; *Robert R. Rathbone (Massachusetts Institute of Technology, Cambridge, Mass.).*

The usual method of transmitting intelligence in a large-scale system of pulsed circuits is to supply a signal pulse on a particular line at a specified time. To test such a system, external equipment is needed which will generate, route, delay, gate, store, shape, and measure pulses. The Electronic Computer Division of Servomechanisms Laboratory, Massachusetts Institute of Technology, has developed a new line of test units for all these operations.

This equipment is designed to operate with positive, 0.1-microsecond half-sine-wave pulses and a minimum pulse period of 0.5 microsecond. Most of the units have a pulse-shaping circuit to insure that output pulses are uniform. Each contains an average of six vacuum tubes, may be mounted on a 19-inch relay rack, and performs some basic function of a pulsed circuit. A standard input and output impedance of 93 ohms permits interconnecting the units as basic building blocks for a large variety of pulsed systems.

Before the adoption of the building-block technique, a special test setup for the Massachusetts Institute of Technology digital computer would require long periods of time to design and construct. After tests, the setup would be worthless, except for its salvage value. By using the new units, the engineer may now build an elaborate array in less than a day. When it is no longer needed, the setup is disassembled and the pieces of test equipment are ready for other uses.

Marginal Checking: Preventive Maintenance for Electronic Equipment; *George C. Sumner (Massachusetts Institute of Technology, Cambridge, Mass.).*

A high degree of reliability must be obtained from modern electronic equipment if its use is to be extended in the future. Because of their size and because of the presence of a memory which remembers incorrect as well as correct information, reliability of electronic digital computers is an even more difficult problem than for more common equipment.

Since most component failures in conservatively designed circuits result from gradual deterioration, checks of performance margins permit removal of failing components before operation failure occurs. By submitting circuits to strained operating conditions such as decreasing screen-grid voltage for amplifiers, the condition of vacuum tubes and other components are checked in place. This preventive maintenance is called marginal checking. The amount of additional equipment needed for detection and signal source switching depends upon the degree of reliability required. In electronic computers detection and source switching can be done with the proper test program of computer instructions, so that the procedure may be highly automatized without excessive additional equipment.

Simply varying power supply voltages is inadequate because particular deteriorated components are not isolated. However, grouping of circuits into sections not used simultaneously gives good isolation.

Preventive maintenance in the form of marginal checking applied to a 400-tube system improved reliability over 50 to 1. Preliminary results indicate that equally good results can be obtained with larger systems.

Electric Equipment for Wire-Drawing Machines; *William E. Zelley (John A. Roebling's Sons Company, Trenton, N. J.).*

All present-day wire-drawing machines fall into one or another of four basic types: single motor, single block; single motor, multiple block, slip type; single motor, multiple block, nonslip type; or multiple motor, multiple block, nonslip type. Each of these types of machines presents a different problem in the selection of motors and control for their most efficient operation.

A comparison of the results obtained with the different types of electric equipment used shows definite advantages in favor of certain equipment for use with some machines, whereas different equipment is needed for other types. It is a well-known fact that a single-motor drive presents a much simpler problem than when a group of motors must operate in synchronism as in the multiple-motor nonslip machines.

The spooling or reeling of wire as it is drawn on the machine presents a problem that has been attacked from several angles in order to provide the necessary change in speed to compensate for the change in reel or spool diameter as the reel fills up and, at the same time, to control the tension in the wire during the entire reeling cycle. A study of the problem presented by the different machines and spooling requirements enables the drawing of some conclusions as to the general type of electric equipment required for each type and to outline a plan for comparison and evaluation of the operating results with the different types of machines in use.

Installation of Wire-Drawing Equipment; *Norman C. Dunbar (John A. Roebling's Sons Company, Trenton, N. J.).*

The proper installation of wire-drawing equipment in a wire mill requires careful planning as does the installation of equipment in any manufacturing plant. While many of the factors affecting plant layout are basic for most industries, there are problems peculiar to the wire industry which need special attention.

Some of the factors which always should be considered are the general location in which the process should take place, space requirements for the wire-drawing and material-handling equipment, areas for stock storage and operating personnel, accessibility of the equipment for maintenance purposes, and provisions for service lines to the equipment.

One of the problems frequently encountered when installing wire-drawing equipment is that of providing an adequate and efficient wire-drawing compound system which can be kept clean. A recent installation was developed to minimize the cleaning problem by designing the system for the utilization of a hydraulic pipe cleaner. During cleaning, one end of each line is opened into a specially designed sump for the ejection of the pipe cleaner and drainage of the water and loosened sludge. The piping arrangement permits cleaning of all main lines without draining the tanks. The tanks are constructed with baffles for trapping and holding sludge, and coils for temperature control. These coils are readily disconnected from their supply headers and also may be removed for cleaning without draining the tanks.

Final Plans Made, Program Announced for Summer and Pacific General Meeting

As reported previously, this year's AIEE Summer General Meeting has been combined with the Pacific General Meeting, which is usually held in August, to form the 1950 Summer and Pacific General Meeting. The Huntington Hotel in Pasadena, Calif., has been chosen as the headquarters hotel and the dates are June 12–16. Pasadena, situated about ten miles northeast of metropolitan Los Angeles, nestles below the majestic Sierra Madre Mountains. It is a city of culture and education with lovely homes and gardens. Its industry largely consists of men, plants, and laboratories turning out highly scientific precision equipment. It is the home of the world-famous California Institute of Technology. Pasadena's greatest fame, however, probably is attributable to the annual New Year's Day "Tournament of Roses" parade and the Rose Bowl football game on the same day. Warm days may be expected in June but the evenings are generally cool and the ladies probably will be more comfortable out-of-doors with a light wrap.

The technical program for the meeting, announced in this issue, is broad in scope, embracing 31 sessions covering subjects falling within the five groups of Institute technical activity, namely: power, electronics and science, industry, communications, and general applications.

Many of the papers will present the latest trends and practices in the generation, transmission, and distribution of electric power, as well as its application to the production of steel, petroleum, mining, and paper. Among these is a report on "Protection of Electronic Power Converters" which is devoted to the problem of the protection of power rectifiers of the size and type usually encountered in railway, electrochemical, and general industrial applications.

Two sessions on transformers will be devoted to the problems involved in the selection, application, and operation of large power transformers.

Buying large power transformers poses many and varied problems. Some of these will depend upon whether the transformer installation is step-up or step-down, and also whether it is intended for load only or for combined load and synchronous condenser operation. Among the other problems may be mentioned choice between 3-phase and single-phase, whether to use autotransformers, choice of transformer impedances, choice of methods of cooling and possibility of planned overloading, oil preservation, and the possibility of reduced insulation contingent on well engineered lightning-arrester application. These and other factors will be discussed by the authors of the various papers.

The papers to be presented have been prepared especially for these sessions. Among the authors are well-known engineers in the utility and manufacturing fields. The data and information to be given in the papers and the expected discussions will be of great benefit to the industry.

TRANSPORTATION

Pasadena hotel guests will find taxicabs or streetcars the most convenient method of getting to the Huntington Hotel.

Los Angeles Biltmore Hotel guests can board chartered busses at the Grand Avenue entrance, leaving Monday morning, June 12, at 8:30, 9:00, 10:00, and 10:30 a.m. Biltmore Hotel bus schedules can be obtained and transportation tickets purchased when registering.

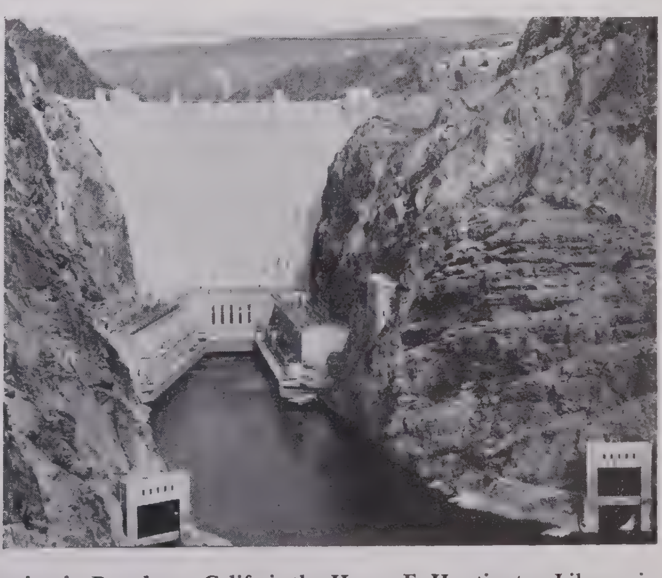
The Pacific Electric Oak Knoll line has a regular stop at the Huntington and can be boarded on Colorado Street in Pasadena or at the 6th and Main Street Station in Los Angeles.

INSPECTION TRIPS

Lockheed Aircraft Corporation, Burbank, Calif. (Monday, June 12, 2:00 p.m.). At this plant, home of the famous *P-38 Interceptor*, *F-80 Jet Fighter*, *P-2V Truculent Turtle*, and *Constellation* transport airplanes, it will be possible to see extensive plant facilities, production methods, and airplanes in current production. It is necessary that the total group be limited to 90 persons, all of whom must be citizens of the United States.

Walt Disney Studios (Monday, June 12; Wednesday, June 14; and Friday, June 16; 2:00 p.m.). At this studio in Burbank, the Silly Symphonies, Donald Duck, and other short subjects are produced, as well as full-length feature pictures such as Snow White and the Seven Dwarfs, Pinocchio, Dumbo, Fantasia, Cinderella, and others. For the convenience of guides and visitors, parties must be limited to groups of 15 to 20 persons, with staggered starting time approximately 15 minutes apart. Four such parties can be handled in one afternoon. Visitors will be shown how the studio operates in approximately the following sequence: development of a story by means of a pictorial script; development of new characters and standardization of their gestures and appearance; production, inking, painting of background

(*Continued on page 558*)



To be visited during the 1950 AIEE Summer and Pacific General Meeting in Pasadena, Calif., is the Henry E. Huntington Library in San Marino, shown above, left. At the right is Hoover Dam, which supplies power to the San Fernando Valley. At receiving station E of the Los Angeles Department of Water and Power, to be inspected also, Hoover voltage is stepped down from 287 kv to 132 kv

Tentative Technical Program

Summer and Pacific General Meeting, Pasadena, June 12–16

Monday, June 12

10:00 a.m. Opening Ceremony

Introduction of Pacific Coast Institute officers and presentation of Pacific Coast delegates. F. Garrison, General Chairman

Address of Welcome, Dr. R. W. Sorenson

10:30 a.m. Annual Meeting

1. Report of Board of Directors. H. H. Henline, Secretary

2. Report of Treasurer. W. I. Slichter

3. Report of Committee of Tellers on vote for nominees for AIEE offices

4. (*a*). Introduction of and presentation of President's badge to T. G. LeClair
(*b*). Response by Mr. LeClair

5. Commemoration of 100th anniversary of the birth of Oliver Heaviside. Dr. Paul S. Epstein, Professor of Theoretical Physics, California Institute of Technology

6. Presentation of Lamme Medal to C. M. Laffoon, Manager of A-C Engineering Department, Westinghouse Electric Corporation

(*a*). The Establishment of the Medal. J. B. Thomas, Chairman, Lamme Medal Committee
(*b*). The Career of the Medalist. A. C. Monteith, Vice-President in charge of Engineering and Research, Westinghouse Electric Corporation
(*c*). Presentation of medal and certificate by President Fairman
(*d*). Response by Mr. Laffoon

7. Any other business that may be presented

8. President's Address. J. F. Fairman

2:00 p.m. Petroleum Industry

CP. Electric Distribution in the Petroleum Industry.** *C. M. Hoag*, The Fluor Corporation, Ltd.

CP. Industrial Distribution.** *M. R. Born*, Shell Oil Corporation

CP. Criteria for the Cathodic Protection of Ferrous Materials in Soils.** *I. A. Dennison*, National Bureau of Standards

2:00 p.m. Safety

CP. 108 Are Missing.** *E. C. Hunt*, Pacific Gas and Electric Company

CP. Safety Tests for Electronic Devices.** *O. G. Wedekind*, Underwriters Laboratories, Inc.

CP. Electrical Work Injuries in California Industries.** *E. E. Carlton*, State of California Department of Industrial Relations

50-184. Effect of Frequency on Perception Currents. *C. F. Dalziel*, University of California; *T. H. Mansfield*, Tracerlab, Inc.

CP.* Electrical Safety in Experimental Laboratories. *C. F. Dalziel*, University of California

2:00 p.m. Electronics

CP.* An Oscillograph Amplifier Using a Transductor as the Input Stage. *G. W. Downs*, *Ralph Morrison*, William Miller Corporation

CP. A Simple Stabilized D-C Amplifier for Use With Electric Analogue Computers.** *Vernon Briggs*, United States Naval Ordnance Test Station

CP. Magnetic Modulators.** *Gunnar Wennerberg*, Lear, Inc.

CP. Recent Trends in the Field of Miniature Electronic Components.** *M. J. Ainsworth*, Bendix Aviation Corporation

CP. Electronics Goes to the Farm.** *David Packard*, Hewlett-Packard Company

2:00 p.m. Conference of Vice-Presidents and District Secretaries

Tuesday, June 13

9:30 a.m. Transmission and Distribution

50-143. Progress Report on 500-Kv Test Project of the American Gas and Electric Company—Corona, Radio Influence, and Other Factors. *Philip Sporn*, American Gas and Electric Service Corporation; *A. C. Monteith*, Westinghouse Electric Corporation

50-141. Desert Measurements of Corona Loss on Conductors for Operation Above 230 Kv. *W. S. Peterson*, *Bradley Cozzens*, Department of Water and Power, The City of Los Angeles; *J. S. Carroll*, Stanford University

50-135. Long-Distance Power Transmission. *S. B. Crary*, General Electric Company

50-161. Interrupting Ability of Horn-Gap Switches. *F. E. Andrews*, *L. R. Janes*, *M. A. Andersson*, Public Service Company of Northern Illinois

9:30 a.m. Computers

CP. Design Features of the INA Digital Computer.** *E. Lacey*, *D. Rutland*, *H. Larson*, *H. D. Huskey*, National Bureau of Standards

CP. Applications of the INA Digital Computer.** *H. D. Huskey*, National Bureau of Standards

CP. University of California Digital Computer.** *P. A. Morton*, University of California

CP. A High-Speed Multiplier for Analogue Computers.** *B. N. Locanthi*, California Institute of Technology

CP. MADDIDA, General Theory.** *F. G. Steele*, Northrop Aircraft, Inc.

CP. MADDIDA, Design Features.** *D. E. Eckdahl*, Northrop Aircraft, Inc.

9:30 a.m. Planning of New Laboratory Facilities

CP. Functional Design of Buildings for Electrical Education.** *J. D. Ryder*, University of Illinois; *W. B. Boast*, Iowa State College

CP. The New Electrical Engineering Building at the University of California.** *C. F. Dalziel*, *T. C. McFarland*, *R. M. Saunders*, University of California

CP. Electrical Engineering Building at Oregon State College Features Functional Design.** *B. H. Nichols*, Oregon State College

CP. A Water Rheostat Using Untreated Water.** *J. F. Engle*, Oregon State College

9:30 a.m. Land Transportation

50-180–ACO.* Power, Pull, and Performance of Electric Locomotives. *A. H. Candee*, Westinghouse Electric Corporation

50-181. Locomotive Wheel-Slip and Wheel-Lock Protection. *R. M. Smith*, General Electric Company

50-182. A New Resilient Class H Material for the Insulation of Traction Motor Field Coils. *J. R. Reed*, National Electric Coil Company of Columbus, Ohio; *J. J. Tyner*

9:30 a.m. Section Delegates Conference

2:00 p.m. Relays and Transmission and Distribution

50-130. 13-Year Lightning Performance of Boulder 287.5-Kv Transmission Lines. *T. M. Blakeslee*, *E. L. Kanouse*, Department of Water and Power, The City of Los Angeles

50-163–ACO.* Methods of Estimating the Lightning Performance of Transmission Lines. *Lightning and Insulator Subcommittee*

50-164. The Bonneville Power Administration Relaying and Reclosing Program. *C. C. Diemond*, *D. L. Wylie*, Bonneville Power Administration

50-140. Relaying Practices and Economical Switching Station Arrangements of the Bureau of Reclamation. *W. A. Morgan*, *R. W. World*, Bureau of Reclamation

2:00 p.m. Applications of Computers to Aircraft Engineering Problems

CP. Automatic Data Handling Techniques Including Recording and Reduction.** *W. D. Bell*, Telecomputing Corporation

CP. Electrical Analogue Computing Techniques for Complex Vibration and Aeroelastic Problems.** *G. D. McCann*, *R. H. MacNeal*, California Institute of Technology

CP. Use of Analogy Computing Techniques for Aeroelastic Problems.** *P. A. Dennis*, *D. G. Dill*, Douglas Aircraft Company

CP. Complex Missile Control System Design and Analysis With the Electric Analogue Computer.** *J. P. Brown*, Lear, Inc.; *C. H. Wilts*, California Institute of Technology

CP. Solution of Problems in Electrical Engineering by Means of Analogue Computers.** *L. L. Grandi*, *D. Lebell*, University of California

2:00 p.m. Western Mining Applications

CP. Hard Rock Mining, San Manuel Project.** *R. P. Diehl*, Magna Copper Corporation

CP. Mining and Refining of Potash.** *G. T. Harley*, International Minerals and Chemical Corporation

CP. Development of the D-C Haulage System for Morenci Mine.** *Felix Berra*, Phelps-Dodge Corporation; *Roy Call*, Westinghouse Electric Corporation

CP. Processes and Equipment for the Garfield Refinery.** *R. J. Corfield*, Kennecott Copper Corporation

Wednesday, June 14

9:30 a.m. Transformers

50-165. Transformer Oil. *E. D. Treanor*, *E. L. Raab*, General Electric Company

CP. Selection of Cooling and Oil Preservation for Power Transformers.** *J. A. Elzi*, Commonwealth Associates

50-166. Development of Preferred Voltage Ratings for Transformers. *H. P. St. Clair*, American Gas and Electric Service Corporation; *H. M. Jalonack*, General Electric Company

CP. Selection, Application, and Operation of Large Power Transformers on Southern California Edison Company System.** *C. L. Sidway*, *L. H. Beebe*, Southern California Edison Company

CP. General Considerations for Banking of Distribution Transformers.** *F. I. Nagle*, *N. K. Yarnell*, Southern California Edison Company

50-167–ACO. Engineering and Economic Considerations Applicable to Large Power Transformer Installations.** *C. M. Short*, Department of Water and Power, The City of Los Angeles; *W. G. Hart*, General Electric Company

9:30 a.m. Western Mining Applications

CP. Electronic Communication Systems for Mine Shafts.** *C. M. Marquardt*, Combined Metals Reduction Company

CP. Conveyer Haulage and Hoisting.** *C. A. R. Lambley*, Pend O'Reille Mines and Metals Company

CP. Electricity in Underground Copper Mines.** *Rollin Kennard*, Anaconda Copper Mining Company

CP. A Low-Voltage Ground Protector Relay for Mine Use.** *A. B. Chafetz*, International Minerals and Chemical Corporation

9:30 a.m. Particle Acceleration and Detection

CP. Cloud Chamber Studies of Cosmic Rays.** *O. D. Anderson*, California Institute of Technology

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* **ACO:** Advance copies only available; not intended for publication in *Transactions*.

** **CP:** Conference paper; no advance copies are available; not intended for publication in *Transactions*.

CP. Operation of the 350-Million-Electron-Volt Berkeley Synchrotron.** *Marvin Martin*, University of California

CP. A 500-Kv Radio-Frequency Power Supply as a Bevatron Injector.** *J. R. Woodyard*, University of California

CP. The Klystron as a High-Power Source for the Electron Linear Accelerator.** *Simon Sonkin*, Stanford University

CP. Proton Linear Accelerators.** *W. K. H. Panofsky*, University of California

9:30 a.m. Telephone Switching

50-168. Interexchange Tandem Trunking in the Los Angeles Metropolitan Area. *W. F. Pfeiffer*, The Pacific Telephone and Telegraph Company

50-158. Crossbar Tandem System. *R. E. Collis*, Bell Telephone Laboratories, Inc.

50-169. Universal Director in Strowger Automatic Telephone Systems. *J. E. Ostline*, Automatic Electric Company

2:00 p.m. Transformers

50-129. Selection, Design, and Operation of Power Transformers on American Gas and Electric Company System. *F. A. Lane, I. W. Gross, P. S. Pugh*, American Gas and Electric Service Corporation

50-134. Selection and Application of Power Transformers. *H. P. Seelye*, The Detroit Edison Company

CP. Selection of Substation Transformers for Growing Loads.** *R. E. Pierce, F. C. Poage*, Ebasco Services, Inc.

CP. Economics of Power Transformer Application.** *J. E. Barkle, R. L. Witzke*, Westinghouse Electric Corporation

50-128. The Choice of Main Power Transformers for Generating Stations. *N. E. Dillow, J. W. Butler*, General Electric Company

50-178. Transformer Sound Level Considerations. *A. J. Maslin*, Westinghouse Electric Corporation. Presentation by title only

50-179. Quiet Transformer Installations—A Problem for Both Equipment and Substation Designers. *I. S. Mendenhall, F. L. Taylor*, The Detroit Edison Company. Presentation by title only

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—PAMPHLET reproductions of authors' manuscripts of the numbered papers listed in the program may be obtained as noted in the following paragraphs.

—PRICES for papers, irrespective of length, are 30 cents to members (60 cents to nonmembers) whether ordered by mail or purchased at the meeting. Mail orders are advisable, particularly from out-of-town members, as an adequate supply of each paper at the meeting cannot be assured. Only numbered papers are available in pamphlet form.

—COUPON books in nine-dollar denominations are available for those who may wish this convenient form of remittance.

—THE PAPERS regularly approved by the Technical Program Committee ultimately will be published in Proceedings and Transactions; also, each is scheduled to be published in Electrical Engineering in digest or other form.

2:00 p.m. Electronics

CP. Use of Reflection Doppler Techniques for Test Range Instrumentation.** *David Kean*, United States Naval Ordnance Test Station

CP. Application of Electronics to Test Range Instrumentation.** *Frederick Ashbrook*, United States Naval Ordnance Test Station

CP. A Precision Timing System for Test Range Instrumentation.** *Thomas Parkin*, United States Naval Ordnance Test Station

CP. Sound Ranging at the Morris Dam Torpedo Ranges.** *R. N. Skeeters*, United States Naval Ordnance Test Station

CP.* Electrical Requirements for Firing Rockets by Induction. *J. P. McClellan*, United States Naval Ordnance Test Station

CP. Determination of the Composition of Surface Layers by Ion Scattering.** *Sylvan Rubin*, Stanford Research Institute

2:00 p.m. Metal Industry

CP. The Rising Tide of Business and Industry on the Pacific Slope.** *Alden G. Roach*, Columbia Steel Company

50-185–ACO.* Electrical Problems of the Steel Plant at Fontana. *George Scheer*, Kaiser Engineers

CP. Features of Electric Arc Furnaces.** *C. C. Brandt*, Bethlehem Pacific Coast Steel Corporation

CP. Electrical Aspects of Joining Large Diameter Pipe.** *H. E. Parks*, Consolidated Western Steel Corporation

CP. The Aluminum Industry in the West.** *F. J. Wood*, Permanente Metals

Thursday, June 15

9:30 a.m. Instruments and Measurements

CP. An Electromagnetic Method of Measuring Oscillating Fluid Flow.** *A. J. Morris*, Office of Naval Research; *J. H. Chadwick*, Stanford University

CP. A Recording Power Frequency Meter Reasonably Independent of Operating Voltage.** *N. M. Albert*, Pacific Gas and Electric Company

CP. Front-of-Wave Impulse Measurement Techniques.** *M. M. Newman, Peter Bellaschi*, University of Minnesota

50-155. Indicating Instruments at the Servomechanism Frequencies. *W. S. Pritchett, R. M. Saunders*, University of California

CP. A Review of Instruments and Practices for Insulation Resistance Measurements.** *W. G. Foster*, Portland General Electric Company

9:30 a.m. Microwave Applications

50-151. Field Testing a Microwave Channel for Voice Communication, Relaying, Telemetering, and Supervisory Control. *D. R. Pattison*, Pennsylvania Electric Company; *M. E. Reagan, S. C. Leyland, F. B. Gunter*, Westinghouse Electric Corporation

50-170. Microwave Applications to Bonneville Power Administration System. *R. F. Stevens, T. W. Stringfield*, Bonneville Power Administration

50-171. Microwave Systems for 960 and 2,000 Megacycles. *R. V. Rector*, General Electric Company; *W. E. Sutter*, International General Electric Company

CP. 940- to 960-Megacycle Communication Equipment for Industrial Applications.** *F. B. Gunter*, Westinghouse Electric Corporation

CP. Problems to Be Solved in the Application of Microwave Equipment.** *R. C. Cheek*, Westinghouse Electric Corporation

9:30 a.m. Protective Devices

50-152. Proposed Basic Impulse Insulation Levels for High-Voltage Systems. *J. E. Clem, J. R. Meador, W. J. Rudge, A. H. Powell*, General Electric Company

50-150. Evaluation of Arrester Lead Length and Separation in Co-ordinated Protection of Apparatus Against Lightning. *T. J. Carpenter, I. B. Johnson, L. E. Saline*, General Electric Company

50-153. Co-ordination of Arrester Location With Transformer Insulation Level. *R. L. Witzke, T. J. Bliss*, Westinghouse Electric Corporation

50-147–ACO.* Protection of Rotating Machines Against Lightning Surges—Insulation Co-ordination Requirements and Protective Measures. *P. L. Bellaschi*, Portland, Oreg.

9:30 a.m. System Planning

50-139–ACO.* Expansion of the Electric Systems in the Pacific Southwest. *H. A. Lott*, Southern California Edison Company

50-144. Power System Planning in the City of Los Angeles. *A. L. Williams, E. L. Kanouse*, Department of Water and Power, The City of Los Angeles

50-138. Expansion of the System of the Southern California Edison Company. *A. A. Kroneberg*, Southern California Edison Company

50-132–ACO.* System Planning in Northern and Central California. *I. W. Collins*, Pacific Gas and Electric Company

CP. A Half-Century of Power Resources Planning.** *G. H. Groh, Harry Wells*, Central Arizona Light and Power Company

50-172–ACO.* A Simple New Resistance-Type A-C Load Flow Board. *W. E. Enns*, Portland General Electric Company

50-173–ACO.* Application of Calculated Risk to Oil Circuit Breaker Modernization Program. *M. J. Lantz*, Bonneville Power Administration

9:30 a.m. Student Technical Session

2:00 p.m. Instruments and Measurements

50-160. Principles of Design of Log-Scale D-C Indicating Instruments. *Allen Stimson C. F. Taylor*, General Electric Company

CP. Output Analysis and Alignment Techniques for Phase-Rotation Single Sideband Transmitters.** *Oliver Whitby, D. R. Scheuch*, Stanford Research Institute

CP. Electrical Measurement of Microsecond-Duration Dynamic Strains.** *L. A. Roberts*, Palo Alto, Calif.

CP. Operation of Electrodynamometer Instruments Through Amplifiers.** *W. G. Hoover*, Stanford University

50-183–ACO.* Use of High-Pressure Mercury Arc Lamps for Pulsed Light Applications. *R. O. Briggs, F. W. Looschen, S. F. Schmidt*, Ames Aeronautical Laboratory

CP. Present Status and Applications of Microwave Spectroscopy.** *W. D. Hershberger*, University of California

2:00 p.m. Conference on Carrier Current

50-162. A Low Noise and Distortion Audio Multiplexing Equipment With High Stability Carrier Supply. *F. S. Beale*, Westinghouse Electric Corporation

CP. Integrated Power Line Carrier System.** *H. S. Lane*, Pacific Gas and Electric Company

CP. Measurements and Tests on Power Line Relaying System.** *R. H. Miller*, Pacific Gas and Electric Company

CP. Methods of Trap Tuning.** *C. R. Canady*, Southern California Edison Company

49-211. Modern Carrier Current Test Equipment and Its Application. *R. L. Brinton*, Pacific Gas and Electric Company. Presentation by title only

2:00 p.m. Conference on Protective Devices

49-280–ACO.* Application Guide on Methods of Neutral Grounding of Transmission Systems. *Working Group of Subcommittee on Fault Limiting Devices*

49-281–ACO.* Application Guide for the Grounding of Synchronous Generator Systems. *Working Group of Subcommittee on Fault Limiting Devices*

49-283–ACO.* Guide for Application of Ground-Fault Neutralizers. *Working Group of Subcommittee on Fault Limiting Devices*

50-154. Development of the Standard for Neutral Grounding Devices. *J. E. Clem*, General Electric Company

2:00 p.m. District Branch Prize Papers

Presentation of District Branch prize papers by the winners from the even-numbered Districts 2, 4, 6, 8, and 10

Friday, June 16

9:30 a.m. Hydroelectric Systems

50-136. The Bridge River Hydroelectric Development. *T. Ingledow, J. H. Steede*, British Columbia Electric Railway Company, Ltd.

50-186. Underground Hydroelectric Power Plants. *P. E. Gisiger*, Companhia Brasileira Administradora de Servicos Tecnicos

50-149. Underground Hydroelectric Power Stations in Sweden. *Ake Rusck, G. Westerberg*, Swedish State Power Board

50-188. The Determination and Allocation of the Capacity Benefits Resulting From Interconnecting Two or More Generating Systems. *C. W. Watchorn*, Pennsylvania Water and Power Company. Presentation by title only

9:30 a.m. Symposium on the Bevatron

CP. Pulsed Power Particle Accelerators.** *George Farley*, University of California

CP. Multipurpose Generators and Controls for High-Energy Particle Accelerators.** *G. L. Godwin, L. A. Kilgore*, Westinghouse Electric Corporation

50-174. Ignitron Converters for High-Energy Particle Accelerators. *J. L. Boyer, C. R. Marcum*, Westinghouse Electric Corporation

CP. Design and Preliminary Operation of the Bevatron With Emphasis on the Magnetic Circuit.** *Duane Sewell*, University of California

CP. Frequency Control for the Bevatron Radio-Frequency Voltage.** *Jack Reidel*, University of California

9:30 a.m. Substations

50-142. A 5,000-Kva Underground Substation. *J. F. Sinnott*, San Diego Gas and Electric Company

50-131. Automatic Control of Ignitron Rectifier Stations. *E. J. Cham, W. A. Derr*, Westinghouse Electric Corporation

50-175. Multistation Supervisory Control, Telemetering, and Communication on Single-Frequency Carrier Channel. *W. A. Derr*, Westinghouse Electric Corporation; *T. C. Wren*, Sierra Pacific Power Company; *J. V. Kresser*, Westinghouse Electric Corporation

CP. Systemwide Fast Response Telemetering.** *G. W. Dupree*, Southwestern Public Service Company

CP. Use of Ultrahigh-Frequency Equipment for Supervisory Control and Telemetering.** *L. E. Ludekens*, Southern California Edison Company, Ltd.

9:30 a.m. Lumber and Paper Mills

50-176. Amplidyne-Controlled Log Carriage Drive. *W. D. Vincent*, General Electric Company

CP. Electrification of a Pulp Mill and Board Machine.** *J. A. Tudor*, Westinghouse Electric Corporation

CP. Electric Equipment for Paper Mill Winders.** *Subcommittee on Pulp and Paper Industry.* Presentation by *F. M. Dorey*

CP. Electric Equipment for Paper Mill Supercalenders.** *Subcommittee on Pulp and Paper Industry.* Presentation by *H. A. Rose*

9:30 a.m. Student Technical Session

2:00 p.m. Excitation Systems

50-137. Hydroelectric Generator Excitation Experience at Grand Coulee. *C. L. Killgore, N. G. Holmdahl*, Bureau of Reclamation

CP. Parallel Operation of Main Exciter Rototrol and Conventional D-C Exciter.** *J. E. Barkle, C. E. Valentine, A. M. Harrison*, Westinghouse Electric Corporation

CP. A Commutatorless Pilot Exciter for Turbine Generators.** *C. Lynn*, Westinghouse Electric Corporation

50-187. Centralized Control Desirable for Single Boiler-Turbine-Generator Units. *J. A. Lind, J. M. Geiger*, Buffalo Niagara Electric Corporation. Presentation by title only

2:00 p.m. Magnetic Amplifiers and Transformers

50-159. The Design of Broadband Transformers for Linear Electronic Circuits. *H. W. Lord*, General Electric Research Laboratory

50-148. General Characteristics of Magnetic Amplifiers. *L. A. Finzi, D. C. Beaumariage*, Carnegie Institute of Technology

50-177. Response Time of Magnetic Amplifiers. *E. L. Harder, W. F. Horton*, Westinghouse Electric Corporation

50-156. The Extension of Amplistat Performance by A-C Components. *R. E. Morgan, H. M. Ogle, V. J. Wattenberger*, General Electric Company

CP. Theory of the No-Load Characteristics of Highly Saturable Reactors With Hysteresis.** *Alfredo Baños, Jr.*, University of California

2:00 p.m. Electronic Power Converters

50-145. High-Voltage Rectifier Equipment and Control for Tube Testing. *S. R. Durand*, Allis-Chalmers Manufacturing Company

50-146. High-Voltage Ignitron Rectifiers. *M. J. Mulhern*, General Electric Company

50-157. Ignitron Pulse Equipment for Particle Accelerators. *C. C. Herskind, J. E. Hudson*, General Electric Corporation

CP. A Brief Pictorial Story on the Early Development of the Mercury Arc Rectifier.** *W. C. White*, General Electric Company

CP. Survey of Operation of Mercury Arc Rectifiers.** *Committee on Electronic Power Converters*

50-133. Protection of Electronic Power Converters. *Committee on Electronic Power Converters.* Presentation by title only

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(*Continued from page 555*)

and action cells; paint laboratory where careful spectrophotometric control of paint manufacture is maintained; the multiplane cameras (these will be of considerable technical interest as they are a unique Disney development); the cutting and editing of motion pictures; sound recording stages and equipment for live action, sound effects, and orchestration; the general plant facilities comprising the electric substation and distribution system, steam plant, and air-conditioning system; the review theater and its technical features (a short subject in current production may be screened for the entire group).

Southern California Edison Company's Redondo Steam Station (Tuesday, June 13, 8:30 a.m.). Southern California Edison Company's new Redondo Beach steam-electric generating station was completed October 10, 1949, when the fourth generating unit was put on the line. Built at a cost of $38,300,000, the station has a capacity of 280,000 kw.

The Redondo Beach plant is one of the most efficient and modern steam-electric generating stations in the world, and is noted for its many unique features and technical innovations. Ocean water, used in vast quantities for cooling purposes, is pumped to and from the station through two submarine tunnels extending 1,900 feet into the sea along the ocean bottom. To prevent the accumulation of troublesome marine growths in undersea conduits, the direction of flow in the tunnels is periodically alternated.

City of Los Angeles Department of Water and Power, Harbor Steam Plant (Tuesday, June 13, 8:30 a.m.). This steam plant, the largest municipally owned steam plant in the United States, has a total rated capacity of 350,000 kw. The first two units at this plant were designed as quick pickup units to provide standby capacity for hydroelectric generation. Each of these units consists of a 65,000-kw 0.8-power factor 3,600-rpm tandem compound turbine, directly connected to an 81,250-kva 60-cycle 3-phase 13,800-volt hydrogen-cooled generator. Steam is supplied at a nominal pressure of 850 pounds per square inch, 900 degrees Fahrenheit. Units 3, 4, and 5 are rated at 75,000 kw, 0.8 power factor, 1,800 rpm, single-cylinder turbine, directly connected to 93,750-kva 60-cycle 3-phase 13,800-volt hydrogen-cooled generators. The Harbor steam plant is designed on the unit system, that is, a single boiler furnishes steam to one turbine. This plant, located in the vicinity of the Los Angeles Harbor, uses sea water in the steam condensers.

California Institute af Technology (Wednesday, June 14, 9:30 a.m.). The nearness of this outstanding technical school and research institute affords unusual opportunity for AIEE visitors to visit the California Institute of Technology campus, as well as other activities not on campus operated by the institute. A tour of the campus will include visits to astrophysics departments, where special exhibits on the Palomar and Mount Wilson observatories have been set up, to the analogue computor and IBM digital computor in the Electrical Engineering Department, a demonstration of high-voltage and dielectric investigation in the High-Voltage Laboratory, a demonstration of high-velocity water tunnel, and the hydrodynamic model testing in the Hydrodynamics Laboratory.

Southern California Edison Company Mesa Substation (Wednesday, June 14, 10:00 a.m.). This inspection trip will be to one of the latest high-voltage switching stations on the Edison system. Transformation from 220-kv to 66,000-volt distribution lines is made. Installed at this location is a 60,000-kva synchronous condenser. At this location is also one of the important branch dispatching centers for the Edison system. This station is also the terminus and an important switching station for carrier current equipment for communication and load telemetering purposes.

City of Los Angeles Department of Water and Power—Receiving Station E (Wednesday, June 14, 1:30 p.m.). Receiving station E of the Department of Water and Power is the dispatching station for the San Fernando Valley area and the terminus for one 287,000-volt transmission line from the Hoover power plant and the terminus for the 110-kv lines from the aqueduct power plants numbers 1 and 2. At this station on the Hoover transmission voltage is stepped

Above, left, is an aerial view of the Harbor steam plant of the Los Angeles Department of Water and Power, to be inspected during the AIEE Summer and Pacific General Meeting. With an installed capacity of more than 350,000 kw, this is the largest municipally owned steam plant in the United States. On Wednesday of the meeting, a demonstration of high-voltage and dielectric investigation is scheduled in the High-Voltage Laboratory of the California Institute of Technology. Shown here at right is a demonstration of a horn gap flashover at about 1,000,000 volts

down from 287 kv to 132 kv by a 195,000-kva transformer bank. One 60,000-kva synchronous condenser is used for voltage control. Two 60,000-kva transformer banks are used to step down from 132 kv to the subtransmission voltage of 34.5 kv. There are two 34.5-kv switch racks, each having 13 positions, one of which feeds the municipalities of Burbank and Glendale with their allocation of Hoover power, and the other supplies the various distribution stations of the Department of Water and Power in the San Fernando Valley area. This station will also serve as the terminus for the Owens Gorge line now under construction.

University of California, Los Angeles Campus (Wednesday, June 14, 1:30 p.m.). This university is expanding more rapidly than any other on the West Coast and because of the quality of the instruction and the extent of research activities, the outstanding architecture of its buildings and spaciousness of its campus should not be missed by visitors to the AIEE meeting. Recently established schools of medicine, law, and engineering are growing rapidly. Among other new buildings to be seen are the newly completed engineering building, which houses chemical, petroleum, fluid mechanics, oil mechanics, and ceramics. A second new engineering building is under construction and this will house aeronautical engineering. At this university is an outstanding computing analyzer and a differential analyzer. Other interesting equipment in the Engineering Department is an electron microscope and an Army Ordnance Gauge Laboratory.

Mount Wilson Observatory and Television Stations (Wednesday, June 14, 7:00 p.m.). An early evening trip will be made to this world-renowned observatory, located on Mount Wilson above Pasadena. A visit to the 100-inch telescope, and to the Astrophysics Museum will be included, as well as other observatory facilities. A description will be given of the work carried on at this observatory as well as some of the separate and interrelated activities at the Palomar Observatory. Nearby is located the Pacific Telephone and Telegraph terminal station for the Mount Wilson–Hollywood microwave radio relay system, which transmits television programs from the Hollywood Central Office to Mount Wilson. From this building parts of television programs are carried by cable to various broadcasting stations. There are seven television stations located on the mountain top, six of them currently broadcasting from this location. Inspection of these facilities will be possible.

Pacific Telephone and Telegraph Company, Los Angeles Communication Center (Thursday, June 15, 9:30 a.m.). A tour through the two large downtown Los Angeles buildings of Pacific Telephone affords an opportunity for members to see in operation southern California's largest communications center. In these two buildings will be seen the following: the terminal of the coaxial cable from the east; the terminal for the Los Angeles-San Francisco microwave radio-relay system; the television service center; facilities for local exchange telephone service; equipment and switchboards for originating, terminating, and "through" long-distance telephone traffic; a crossbar tandem switching office; information and intercepting switchboards; facilities for providing and monitoring radio program network service; an audichron that automatically provides continuous time-of-day service; facilities for telegraph and leased wire service; a switching center for teletypewriter exchange service; facilities and switchboard positions for mobile and ship telephone service; terminal for Los Angeles–Catalina Island radio-relay system.

Kaiser Steel Corporation, Fontana Works (Thursday, June 15, 1:30 p.m.). Located at Fontana, Calif., adjacent to the city of San Bernardino on a 1,300-acre site, this plant is a fully integrated steel mill, the first of its type on the Pacific Coast. It is the only steel mill on the Coast with its own coke ovens and blast furnaces as well as open hearth furnaces and steel finishing facilities. In addition to pig iron and coke-oven by-products, it produces semifinished and finished steels as follows: plate, large and small structural shapes, continuous weld pipe, hot- and cold-rolled strip, skelp, carbon and alloy bars, and foundry products. A complete tour of this plant should be one of the highlights of the Summer Meeting.

KFI-TV Television Studio (Thursday, June 15, 1:30 p.m.). This inspection trip to the

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Future AIEE Meetings

Summer and Pacific General Meeting
Huntington Hotel, Pasadena, Calif.
June 12–16, 1950
(Final date for submitting papers—closed)

Conference on Domestic Appliances
Hotel Cleveland, Cleveland, Ohio
June 20, 1950

Middle Eastern District Meeting
Lord Baltimore Hotel, Baltimore, Md.
October 3–5, 1950
(Final date for submitting papers—July 5)

Fall General Meeting
Skirvin Hotel, Oklahoma City, Okla.
October 23–27, 1950
(Final date for submitting papers—July 25)

1951 Winter General Meeting
New York, N. Y.
January 22–26, 1951
(Final date for submitting papers—October 24)

studios of station *KFI-TV* will not only include a complete inspection of the studio, associated control room, and other equipment, but also participation in a day-time television program.

Palomar Observatory (Friday, June 16, 8:30 a.m.). In order to see this much talked of project, a special all-day trip has been arranged. The total round-trip distance from Pasadena by bus is 260 miles, and it is suggested that the trip only be undertaken by those who will suffer no ill effects from the time and distance involved in such long rides. The coastal and mountain scenery will be most interesting. The opportunity to visit the 200-inch telescope to see it in operation, as well as the other smaller telescopes, and the Schmidt telescope will make the trip more than worth while for those who go.

Sunland-Tujunga Telephone Company (Friday, June 16, 1:30 p.m.). In this telephone exchange (Florida) is one of the first and most complete installations of automatic toll ticketing and automatic toll accounting procedures. Through this exchange approximately 6,000 local service subscribers have access by direct dialing to 1,250,000 telephones in the Los Angeles metropolitan area. The dialing operation is all that is necessary for calls to be made and completely recorded so that toll charges can be billed at the end of the billing period, without switchboard personnel, typists, or adding machine operators. No development in automatic telephone switching during the last 10 or 15 years has stirred the interest of telephone engineers and operating executives as much as that which can be demonstrated at this modern independent exchange.

ENTERTAINMENT

A full program of events has been planned for the entertainment of members and guests attending the meeting, ranging from a luncheon on Monday at noon ($2, including tax and tips), and movies in the evening, to Tuesday's informal barbecue and aquacade show ($4, including tax and tips) and the inspection trip to Mount Wilson on Wednesday. Thursday evening will be highlighted by a banquet and show around the Huntington Hotel pool ($6.50, including tax and tips). Since the maximum number who can attend the Monday luncheon meeting, Tuesday night's aquacade, and the banquet is limited by facilities of the hotel, tickets for these affairs should be purchased at the time of registration.

In addition to the foregoing, a number of special events have been planned for the ladies, including an informal garden tea, a trip through Hollywood and Beverly Hills, a tour of the Huntington Library, Art Gallery, and Botanical Gardens in San Marino, and the historic Mission San Gabriel, and an audience participation show at television station *KFI-TV*.

For complete details of the entertainment program, see the May issue (*pp 465–6*).

SPORTS

Golf and tennis have been arranged for the pleasure of registered male members and guests, and a number of additional details have been announced.

Golf. The annual golf tournament will be a one-day affair, for men only, of 18-hole medal play. No match play is provided. The tournament will be held at the Brookside Park Golf Course on Tuesday morning, June 13, for AIEE members registered at the meeting. Players will compete for the Mershon Golf Trophy (winner, 18-hole medal play at handicap). A suitable prize will be awarded to the Mershon Trophy winner. Players will be divided into suitable flights and prizes for low gross, low net, and several blind bogey prizes will be given in each flight.

AIEE members from Districts 8, 9, and Vancouver, British Columbia, Canada, who are registered at the meeting, will compete for the John B. Fisken cup (low net, 18 holes).

The entry fee of $3, which includes the greens fee, is to be paid at the first tee. Transportation will be provided for when desired and must be arranged for at the Golf Registration Desk in advance. Caddies are not available at this course. The committee will try to arrange to have caddies imported if such desires are indicated on the registration card.

Tennis. The tennis events will be played on the Huntington Hotel courts. Events will be arranged for at the Sports Registration Desk for singles and doubles play and participants must keep in touch with this desk for pairings. AIEE members and guests who are registered at the meeting will compete for the Mershon Tennis Trophy, and prizes will be awarded to the winner and runner-up. The winner and runner-up of the doubles tournament will be awarded suitable prizes. The entry fee will be $1 per person.

REGISTRATION

It will be helpful to all concerned if the mailed advance registration card is filled in and returned promptly. The registration fee will be $3 for members and $5 for nonmembers. No fees will be required from students or families of members. Remittance should not be enclosed; fees will be collected when registering. For the convenience of those arriving early, the Registration Desk in the Huntington Hotel will be open from 5:00 p.m. to 9:00 p.m., Sunday, June 11.

For information on housing accommodations at the Huntington and other hotels in the vicinity and at the California Institute of Technology, see the May issue of *Electrical Engineering* (*pp 464–5*).

North Eastern District Holds Successful Meeting in Providence

Providence, R. I., was host to a 3-day meeting of the AIEE North Eastern District, April 26–28, 1950. A program of broad interest was arranged and 35 papers were presented in eight sessions in addition to 21 student papers, which were presented in two panels. Important meetings were held, including an all-day meeting of the Board of Directors on April 27, a meeting of Vice-Presidents, the Planning and Co-ordination Committee, a dinner meeting of the District Executive Committee, and a luncheon meeting of Student Branch Chairmen and Counselors. On the social side, there was a banquet at the Sheraton-Biltmore Hotel on one of the evenings and a dinner at the Johnson's Hummock Sea Grill, as well as a full program for the ladies, including a trip to Newport. Inspection trips were taken to nearby industries.

THE BANQUET

The principal speaker at the banquet held at the Sheraton-Biltmore Hotel was Truman H. Safford of the Charles T. Main Company, who gave a very interesting illustrated lecture on "Water Power in New York and New England." Beginning with the early settlers who brought with them the knowledge on how to build water wheels, Mr. Safford chronologically and historically took the audience through the many developments up to the St. Lawrence Project and the immense amount of power available. This power, however, would not be available to New England because of the remoteness of the load centers and the industrial development expected in upper New York State in the next ten years.

Profiles of the important rivers in New England and their storage facilities were discussed. In connection with the early projects, it was interesting to note that many villages were fixed in location by the water available; how right the settlers were in the selection of sites was proved later by development of the same sites into large hydroelectric projects.

President Fairman briefly addressed the gathering and appealed to the ladies present to do a job for the organization. Knowing how busy and tired husbands are, he suggested that the ladies get out the scissors and clip the card from the March issue on "Poll of Institute Opinion," get their husbands to fill in the three little squares, and see to it that the cards are mailed to Institute Headquarters.

The Chairman of the Providence Section welcomed members and guests to the banquet, introduced Abram J. Moore who acted as Toastmaster, as well as other officers of the District and the Institute.

INSULATED CONDUCTORS

Papers were presented in the session on insulated conductors, with Herman Halperin presiding, which were well received and widely discussed by prominent people in the cable industry. The use of an accurate modern shearing bridge, a single-phase bridge, for measurement of power factor in 3-phase cables was described by E. W. Greenfield of the Anaconda Wire and Cable Company. In discussion of the subject, Dr. W. B. Kouwenhoven raised the question as to what effect the rotating field would have on the losses in nonbelted types of cable. The author replied that the rotating field played no part in the matter in nonbelted types of cables. He hopes some time to analyze the experiences with the 3-phase field in belted types of cables.

The second paper, "Electric Cables for the Mining Industry," was presented by B. J. Mulvey of the General Electric Company. Several of the discussers commented to the effect that this was a very fine summary of cable practice in the mining industry. In regard to trailing cables, the authors brought out the fact that there is not enough known about the load or diversity operation of these cables, and it was suggested that a survey would be of great interest to all cable engineers. Several of the discussers, including Dr. R. J. Wiseman, questioned the suggestion in the paper to operate cables at 75 degrees centigrade. Because of the safety requirements and the severe handling, Dr. Wiseman suggested designing for 75 degrees centigrade and operating at 60 degrees centigrade. In the closure, Mr. McKinley explained that the 75-degree centigrade suggestion was intended to apply only to trailing cables to large shovels, in cases where shovels are getting larger and also where the cables are larger so as almost to require two cables. He pointed out that it is in such applications that advantage can be taken of the 75-degree centigrade rating.

The third paper dealt with "Failures of Rubber Insulation Caused by Soil Microorganisms" and it was presented by J. T. Blake of the Simplex Wire and Cable Company. In the presentation, Mr. Blake explained that they had been investigating in the laboratories for the last five years the effect of micro-organisms on rubber buried in the ground without benefit of lead. Tests have been devised simulating optimum accelerating conditions and the synthetic rubbers or butyl insulations are not accompanied by visible pitting. Attempts have been made to correlate fungus growth with bacteriological attacks and the neoprene jackets afford some protection but there is the chance of food streaks. All of the discussers agreed that the paper gave to industry valuable insight into another type of cable failure. K. S. Wyatt of the Phelps Dodge Copper Products Company cited contemporary experiences in South and Central America. In conclusion, Mr. Blake explained that the materials which tend to resist fungi also tend to resist bacteria. In the GRF type of insulation, it is probably fatty acids which destroy the material and in rubber it is probably protein and hydrocarbons. All failures due to soil microorganisms do not necessarily take place in the tropics.

INSTRUMENTS AND MEASUREMENTS

The first paper in the session on instruments and measurements, with F. N. Tompkins presiding, was "A New High-Accuracy Counter-Type Tachometer" by T. M. Berry and C. L. Beattie, both of the General Electric Company and read by the latter. The equipment described was developed in demand for a tachometer of high accuracy, this being 0.03 per cent or better. The tachometer consists of three units: a pulse generator driven by the rotating machine; an electronic counting unit; and a remote indicator on which is shown the average speed over a certain period of time. It was brought out that this instrument has proved highly satisfactory in testing the efficiency of steam and gas turbines, where the output power is obtained from speed and torque measurements. An electric typewriter or other printer may be coupled to the system so that a permanent record of the speed may be available, thus eliminating the necessity of a man observing and recording the figures.

A. H. Foley of the General Electric Company presented the second paper, "A Direct Reading High-Voltage Capacitance Bridge." This network, in contrast with the conventional Schering bridge, is direct reading for both dissipation factor and capacitance; it has a fixed guard adjustment, and so its operation is simplified. The method of phase-angle compensation, which may be either positive or negative as required, employs adjustment of the phase angle of the standard capacitor. A capacitance accuracy of 0.1 per cent and a dissipation factor accuracy of better than 0.0001 per cent is possible with this bridge for rapid production measurements by nontechnical personnel.

"The Use of Electric Strain Gauges in Dimensional Measurement" was the title of the paper read by E. L. Watlet of the Brown and Sharpe Manufacturing Company. The heart of this type of gauge is a bonded resistance-wire strain gauge, four of which are used connected in a bridge circuit. The output of this circuit is amplified through three stages, rectified in a copper-oxide rectifier, and the output is read on a meter calibrated in thousandths of an inch. The strain gauge unit is incorporated in a cartridge, which can be screwed into a part to be measured or similarly attached to a specially designed measuring device. Over-all direct measurements or variations of length between limits are possible, as well as inside diameters, up to 1/100,000 inch.

The fourth paper of the session was "Power Measurement by the Hook-on Method" by A. J. Corson and A. L. Nylander of the General Electric Company, and was presented by the latter. The equipment consists of a removable magnetic structure which encircles a current-carrying conductor by means of which the current component is measured. This structure provides a circuit for the magnetomotive force, which is a unique function of the current, and is applied to a secondary winding or directly to an instrument mechanism. This method has been extended to measure active and reactive power and the instrument described in this paper is a self-contained hook-on wattmeter capable of measuring from 3 to 300 kw.

Two other papers were presented by title only; these were "A New Device for Calibrating Watt-hour Meters" by H. F. Robison and W. H. Wickham of the Commonwealth Edison Company and "Resistance Wire Strain Gauges as Elements of the Wheatstone Bridge" by Vincent Petrucelly, Jr., of the American Machine and Foundry Company.

ROTATING MACHINERY

Four papers were presented in the session on rotating machinery with W. R. Hough, Chairman of the Technical Committee on Rotating Machinery, presiding. The first paper, which dealt with "Analysis of Synchronous Machine Short Circuits," was presented by title only. The second paper, "Variable-Speed Drive Constant-Frequency Alternator" by G. G. Gould of the Naval Ordnance Laboratory, was discussed by P. H. Trickey. The third paper was on "Calculation of Capacitor-Excited Induction Generator Performance" by J. B. Friauf of the Bureau of Ships. In the last paper, Gabriel Kron of the General Electric Company presented "Equivalent Circuits of the Shaded-Pole Motor With Space Harmonics." In discussion of this paper, P. H. Trickey complimented the author on having done a very splendid job in working out the equivalent circuits for this type of machine even if harmonics had not been considered. R. G. Dobbin of the General Electric Company, Fort Wayne, Ind., explained that they had built and tested a special shaded-pole motor and that three out of four points checked very closely with Mr. Kron's work. The starting point was the one which was out. In the closure to the second paper, G. G. Gould expressed his appreciation of Mr. Trickey's comments and explained that his company had decided to work on a magnetic fluid clutch because it is not like friction clutches and is free of wear. If graphite had been used as Mr. Trickey suggested, no difficulty would have been encountered.

MINING AND METAL INDUSTRY AND MANAGEMENT

Two papers were presented at the session on wire drawing applications, presided over by E. W. Davis: "Electric Equipment for Wire-Drawing Machines" by W. E. Zelley and "Installation of Wire-Drawing Equipment" by N. C. Dunbar, both authors being with John A. Roebling's Sons Company.

Mr. Zelley grouped the various types of wire-drawing machines in common use into four classifications: single motor, 1- or 2-die machines; single motor, multple-die slip machines; single motor, multiple-die nonslip machines; and multiple-motor, multiple-die nonslip machines. He discussed the various requirements for the different types of machines in regard to the power, speed, and so forth of the drive motors, as well as the economic aspect in the ferrous and nonferrous fields.

The proper arrangement of wire-drawing equipment in a copper wire mill together with the necessary manufacturing facilities were considered in the second paper presented by Mr. Dunbar. He discussed the wire-drawing and annealing and the subsequent possible operations of tinning, cold rolling, bunching, stranding, insulating, or weaving, then he considered the factors affecting the planning of an installation. These are

1. General location in which the process should take place.
2. Area needed for machines including controls and auxiliary equipment.
3. Space needed for operating personnel.
4. Area needed for supply and finished stocks and material handling equipment.
5. Accessibility of machine for maintenance purposes.
6. Provisions for electric power, air lines, water, wire-drawing compounds, drains, and so forth.

Inasmuch as the local conditions, both physical and financial, play an important role, the considerations in this paper were kept in a general form and so are widely applicable.

"The Engineer in Large-Scale Affairs" was the general theme of two papers presented in the latter half of this session. L. L. Bosch of Jackson and Moreland, Engineers, discussed "The Responsibilities of a Consulting Engineer." He stressed the fact that every engineer should ask himself if he is growing up; if he is a good citizen; and if he works as he should with management. Engineers should broaden their interests far beyond the narrow confines of their professional interests and endeavor to add stability to society for the good of humanity. Every engineer should support and take an active part in technical and professional societies, inasmuch as they provide an exchange of ideas and keep him from growing stale mentally.

Specifically, the consulting engineer must know his clients' problems, both from an engineering and economical viewpoint. He has a basic responsibility and must be unafraid to be frank with his client.

John Atkinson, City Manager of Cambridge, Mass., presented the second paper, "Responsibilities of a City Manager." He urged his listeners as engineers to take more of an interest in their local civic affairs. There are many phases of city, county, or state governments which would be conducted more efficiently and more economically if there were engineers who had some say as to the disposition of funds, the choice of operating and supervisory personnel, and so forth—such matters as water supply, housing, street cleaning, and fire and police departments.

COMPUTING DEVICES

In a well-rounded symposium, five papers by authors from the Electronic Computer Division, Servomechanisms Laboratory, of the Massachusetts Institute of Technology were presented. The first of these papers, by C. Robert Wieser, was sponsored by the Watson Laboratory, United States Air Force, and the Office of Naval Research. The other four were in connection with "Project Whirlwind" sponsored by the Office of Naval Research.

The present status of digital computers in control systems was reviewed by C. Robert Wieser and their progress in the next few decades was predicted. He explained that, contrary to popular belief, large-scale digital computers are still in the development stage, and said that it would probably be 15 to 20 years before they are applied to automatic control systems. In the presentation, he referred to two types of control systems; one type dealt with information processing where the logic is simple and the procedure repetitive such as the control of the circulation of a weekly magazine with several million subscribers, keeping insurance records, inventory control, and military logistics. The second type of problem, based on much more complex logic, was the control of several independent quantities. An example would be the automatic control of air traffic approaching a busy airport by rapidly scanning information so that the computer would have virtually a continuous grasp of the behavior of the whole system.

Other papers dealt with the Massachusetts Institute of Technology electrostatic storage tube which was described by S. H. Dodd; "Computer Experience in Extending Tube Life," by E. S. Rich; "Marginal Checking—Preventive Maintenance for Electronic Equipment," by George C. Sumner; and "New Developments in Pulsed Circuit Test Equipment," by R. Rathbone. The last-named paper dealt with a new line of test units which will generate, route, delay, gate, store, shape, and measure pulses. By employing the building block technique, the portable units can be quickly set up and dismantled for the various test setups required.

GENERAL INDUSTRY APPLICATIONS—TEXTILES

The first paper presented at the session devoted to the textile industry was "The Use and Misuse of Electric Equipment in Textile Mills" by S. Cowan of the Factory Insurance Association. This session was presided over by R. J. Demartine.

Mr. Cowan confined his remarks to cotton mills and those processing cotton and similar synthetic or natural fibers. He traced the history of fires in mills from the start of the industry showing that fire losses steadily declined as fire protective devices were improved until they reached a record low just before World War I. At that time most of the textile machinery was driven by belts and shafting powered by water wheels or steam engines.

After 1918 the cotton mills began to be expanded and modernized and this progress was in the main electrical, first by large electric motors and their controls and later these were replaced with individual motor drives, eliminating belts and shafting. During this period the fire loss downward curve reversed and with the increase in use (and misuse) of electric equipment, the fire losses have been steadily increasing.

Mr. Cowan then analyzed some of the electrical fire hazards which are found in many mills and explained how they could be reduced or in many cases eliminated entirely by the use of modern equipment especially designed for use where there is an excess of "fly" or lint in the air.

C. F. Hedlund of Factory Mutual Insurance Company showed a motion picture, "How Fires Start in Industry." Although this did not apply in the main to textile mills, a great number of potential fire hazards in factories and warehouses were shown which were of general interest.

"Electronics in the Textile Industry" was the title of the paper read by L. T. Jester of the General Electric Company. The use of the vacuum tube has given measurements and quality control of sliver, yarns, and the finished cloth a new meaning inasmuch as readings and monitoring can be conducted continuously and, in many instances, automatically. Mr. Jester described several adaptations of electronic equipment to a loom; in one, the loom is stopped automatically when a bad pick is liable to occur by means of U-shaped metal detectors in the lay near the shuttle boxes and a metallic plate on the shuttle. When the shuttle passes the metallic plate, a magnetic circuit is closed and a voltage is induced in a detector coil. This voltage is amplified and if the shuttle is on time just before it enters the box, the signal prevents braking from being applied and the loom continues. On the contrary, if the shuttle is late, the absence of a signal from the detector at the proper time stops the loom before the lay can touch the shuttle.

Mr. Jester explained the functioning of electronic applications to other mill equipment, such as quality control of cloth as it is woven by the use of an electronically controlled let-off drive on a loom by means of a tension control; a photoelectric cloth detwister; an electronic relay application to a high-speed seam detector; a yarn deviation meter; a controller of dielectric heating and twist setting; and the beta-ray thickness gauge.

"The Application of Single Motor Drives to the Textile Finishing Industry" by the Textile Subcommittee of the General Industry Committee was divided into two parts. The first, on slip-ring a-c motors and d-c constant-voltage variable-speed motors, was read by F. D. Snyder of the Westinghouse Electric Corporation, and the second, on a-c adjustable-speed motors, was read by C. F. Savage, Jr., of the General Electric Company.

BASIC SCIENCES

At the basic sciences session of the North Eastern District Meeting, presided over by N. S. Hibshman, Dean of the School of Science and Technology at Pratt Institute, Brooklyn, N. Y., five papers were presented. G. M. Anderson of the Carnegie Institute of Technology read a paper entitled "The Calculation of the Capacitance of Coaxial Cylinders of Rectangular Cross Section." L. M. Vallese of Duquesne University presented a paper, "Density Distribution of Transient Currents in Conductors." A. Boyajian of the General Electric Company read a paper, "The LaPlace Transform." "The Use of the Heaviside Null-Unit Function in Operational Systems Based on the LaPlace Transformation," was presented by J. J. Smith and P. L. Alger of the General Electric Company and read by the former. Gabriel Kron read a paper entitled "Classification of the Reference Frames of a Synchronous Machine."

SPECIAL INDUSTRY APPLICATIONS AND HEATING

Considerable interest and discussion centered about a paper entitled "Conductive Rubber Radiant Heating Panels" by R. C. Cassidy of the United States Rubber Company, which was presented by proxy. The paper described the advantages of using USKON panels made of laminated construction with conductive rubber layers sealed between layers with impregnated paper insulation and backed by 3/16-inch asbestos board. When assembled, the panels present the same appearance as standard interior wall boards, and they are installed in the ceilings. The panels operate on 220 volts and are made in two wattage densities, radiating 17 watts per square foot and 22 watts per square foot. Connections are made by two methods—a junction box mounted on the back in the center of each panel or aluminum foil strips down the sides of each panel in raceways. The system was reported to have economic advantages such as reduction of initial load, elimination of excess capacity, less installed wiring, and more uniform regulation. Most of the installations have been made in the Pacific Northwest, the Tennessee Valley Authority area, and around Chicago, totaling about 400 in number. In response to a question with regard to aging deterioration, the author explained that aging tests predict that life of the rubber would be somewhere between 30 and 40 years, with the resistivity increasing as time goes on.

Other papers in the session dealt with "Determination of Effective Oil Temperature in a Transformer" which was presented by M. F. Beavers of the General Electric Company, and "Transverse Flux Induction Heating," presented by R. M. Baker of the Westinghouse Electric Corporation. In the presentation of the latter paper, the author said that the system was developed to heat nonferrous strip and that the transverse flux induction heating method was the only practical means of accomplishing this result with an efficiency of about 80 per cent. The scheme can handle strip of thicknesses from 10–50 mils with frequencies from 50–10,000 cycles so that oscillating equipment is not required.

STUDENT TECHNICAL SESSIONS

Nineteen undergraduate papers and two graduate papers were presented in two Student Sessions, Panel A and Panel B. Richard Beschle of Worcester Polytechnic Institute was the winner of the undergraduate competition in Panel A, and R. D. Scheuer of Rensselaer Polytechnic Institute was the winner in Panel B. A runoff was to be held later to determine the winner of the District Branch Paper Prize Competition. In the graduate class, Bernard H. Rudwick of Cornell University was judged the winner. Many of the papers were of high quality and the oral presentations were excellent. The papers presented were as follows:

Panel A

W. H. Manning, presiding

"Transistor Circuits." Florian Shnurer, Union College

"The Theremin." Arthur H. Swenson, Union College

"The Development of Microwave Astronomy." Douglas W. Anderson, Cornell University

"An Empirical Approximation to the Magnetization Curve." J. F. Bartram, Yale University

"The Magic X; an E Field Rotating Joint." A. R. Perrins, Yale University

"Television." A. S. Luftman, Northeastern University

"A Pulse Generator for Control of Artificial Respiration." B. L. Friedman, Northeastern University

"*WHUS*, a College Broadcasting Station." Albert G. Grimaila, University of Connecticut

"Some Practical Requirements for Observing Ultrasonic Phenomenon by the Sahlieren Method." Gifford W. Neill, University of Connecticut

"Distortion Measurement by Sweep Methods." Richard Beschle, Worcester Polytechnic Institute

"A VandeGrafi-Type Electrostatic Generator." Ralph Partridge, Worcester Polytechnic Institute

Panel B

W. A. Von Winkle, presiding

"High-Speed Induction Motors for Grinding." John W. Luce, Norwich University

"Design and Construction of a Capacitor Meter." R. D. Scheuer, Rensselaer Polytechnic Institute

"Transient Response Time of Saturable Reactors." M. F. Maguire, Rensselaer Polytechnic Institute

"Magnetic Recording, Past and Present." Ernest H. Beals, Brown University

"Electronic Beam Deflection Meter." Conrad P. Phaneuf, Charles M. Billmyer, Donald A. Elderkin, Joseph L. Goodman, Rhode Island State College

"The Use of Electro-Mechanical Analysis in the Investigation of the Riding Ease of an Automobile" Joseph E. McDermott, Syracuse University

"A Functional Survey of Analogue Computers." Sanford L. Rosing, Syracuse University

"The Reproduction of Tube Characteristic Curves on the Cathode-Ray Oscilloscope." Herbert S. Ingraham, Jr., University of Maine

Graduate

"A Nonlinear Electrical Analogy for Pipe-Line Networks." Bernard H. Rudwick, Cornell University

"Instrument Transformers." Wayne Batteau, Harvard University

LUNCHEON MEETING OF DISTRICT BRANCH COUNSELORS AND CHAIRMEN

After the sessions, the luncheon meeting of District Branch Counselors and Chairmen was held with the following guests: President James F. Fairman, Secretary H. H. Henline, Vice-President Victor Siegried, Vice-Presidential Nominee J. G. Tarboux, Professor F. O. McMillan, Chairmen of the Committee on Student Branches, and the winners of the Prize Paper Competitions. President Fairman commented that rather than take the time to discuss student affairs at the luncheon, he suggested that those present read his article in the present issue of *Electrical Engineering* entitled "To Our Student Members" (*pp 483–4*). Secretary Henline extended greetings to those present.

Among the matters considered were the following: the question of increasing the student dues, the possibility of a traveling Secretary to visit the Branches, a certificate of award for Branches, ways of increasing student interests, ways of increasing student enrollment. Committees were appointed to take care of some of the business. Henry F. Cooke of Syracuse University was unanimously elected Chairman of the District Committee on Student Activities.

LADIES' PROGRAM

In addition to the informal banquet and the dinner, a busy time was arranged for the ladies by Mrs. H. C. Rankin, Chairman of the Ladies' Program Committee. The first day of the meeting a "Get-Acquainted" luncheon and bridge was held at the Warwich Country Club, overlooking Narragansett Bay. On the following day, a scenic tour was taken to historic Newport, with a visit to the "Breakers," beautiful mansion of the late Cornelius Vanderbilt, and luncheon at Christy's on the Wharf at Newport. On Friday morning, a tour was taken to the Trifari, Krussman and Fishel, Inc. plant, where the well-known Trifari costume jewelry is made.

INSPECTION TRIPS

During the meeting, inspection trips were taken by many guests to the Owens-Corning Fiberglas Corporation, Brown and Sharpe Manufacturing Company, the Manchester Street plant of the Narragansett Electric Company, the vehicle maintenance shops of the United Electric Railways Company, and the United States Rubber Company. The visit to the Owens Corning Fiberglas plant, which is one of the largest and newest types of plant producing glass yarn and glass cloth for industrial and general use, was very popular.

COMMITTEES

Chairmen of the committees which made the arrangements were as follows:

E. R. Coop, *General Chairman;* E. M. Adams, *Finance;* E. G. Sturdevant, *Technical Program;* R. H. Porterfield, *Publicity;* F. N. Tompkins, *Student Program;* H. C. Rankin, *Hotel and Registration;* H. A. Baines, *Entertainment;* H. R. Blomquist, *Trips and Transportation;* Mrs. H. C. Rankin, *Ladies' Program*

414 Attend Second Electric Welding Conference

With a total attendance of 414, the second Conference on Electric Welding, sponsored by the AIEE acting in co-operation with the American Welding Society and the Industrial Electrical Engineers' Society of Detroit, was held in Detroit, Mich., April 5–7, 1950. Technical sessions on arc welding, research and equipment, instrumentation, special welding processes, and equipment and power supplies for resistance welding attracted personnel representing research groups, equipment manufacturers, and users.

Most popular innovation at the conference was evening demonstration sessions sponsored by the Detroit Section of the American Welding Society. Demonstrations and exhibits were presented by 24 companies active in the electric welding field. Inert gas-shielded arc welding, flash welding, spot welding, stud welding, and measurements were among the subjects for which latest equipment and techniques were presented.

Shown at the recent Conference on Electric Welding held in Detroit, Mich., are, left to right: G. W. Garman, Chairman of the local committee; L. P. Windsor, Chairman, Arc Research Session; W. G. Bostwick, Chairman, Resistance Welding Equipment Session; C. E. Smith, Secretary, Power Supply Session; J. F. Deffenbaugh, Vice-Chairman, Publication Committee; T. J. Crawford, American Welding Society representative on Executive Committee; S. W. Luther, Vice-Chairman of the local committee; and E. D. Kane, Chairman, Registration Committee

Domestic Appliance Conference to Be Held in Cleveland, June 20

A one-day Technical Conference on Domestic Appliances will be held at the Cleveland Hotel, Cleveland, Ohio, on June 20, 1950. The conference will be sponsored by the AIEE Committee on Domestic and Commercial Applications, General Applications Group.

L. P. Geldhof, Vice-President of Engineering of the Nineteen Hundred Corporation of St. Joseph, Mich., will present a paper on "Engineering Problems in Automatic Washer Design" at the morning session. This will be followed by a luncheon at which R. C. Hienton, General Sales Manager, Cleveland Electric Illuminating Company, will talk on "Appliance Design and Utility Growth." A paper entitled "Electric Range Unit Development" will be presented by E. N. Calhoun, President of the Edwin L. Wiegand Company, Pittsburgh, Pa., at the afternoon session, followed by W. R. Milby of The Detroit Edison Company who will read a paper, "Electric Range Maintenance and Repair."

The Ohio Bell Telephone Company is making available a limited number of tickets to see the Cleveland Indian–New York Yankee night baseball game. Anyone interested in attending this event should notify Warren Chase, Chief Engineer of the Ohio Bell Telephone Company, Cleveland.

The registration fee for the conference will be $2.

The committee in charge of arrangements for the meeting consists of R. L. Oetting, J. C. Strasbourger, C. J. Beller, Warren Chase, and W. T. Clark. T. H. Cline is Chairman of the Subcommittee on Domestic Appliances.

New Lightning Bibliography Issued for Years 1936-1949

In 1937, the AIEE Lightning and Insulator Subcommittee published the AIEE Reference Book in which were reproduced more than 200 of the important papers on lightning and lightning protection published in English during the period 1918–35. With a view to the publication of a second such book, the subcommittee began in 1944 to review papers published after 1935. By 1945, it was found that the costs of publication were prohibitive and the project for the publication of the second AIEE Lightning Reference Book was dropped. The preparatory work on the book, however, showed that many valuable studies of lightning and allied subjects had been made and that many hundreds of papers had been published since 1935. The work of review and listing thus was continued for papers published through 1949 and a bibliography has just been issued which should prove valuable to those working on problems of lightning and lightning protection. S. K. Waldorf is the Bibliography Editor.

The 1936–49 AIEE Lightning Reference Bibliography is composed principally of references on lightning and related topics published from January 1, 1936, to December 31, 1949, in most of the better-known English-, French-, and German-language journals on electrical engineering or physics. Included in the bibliography are the titles of about 750 articles or books and names of about 550 authors.

The bibliography consists of two principal parts—the Subject Section and the Author Section. The Subject Section is subdivided into the following 18 classifications: Arrestors and Other Protective Devices; Cables and Communications; Co-ordination of Insulation; Counterpoise; Distribution; Expulsion Protective Gaps; Ground Fault Neutralizers (Peterson Coils); Grounding; Impulse Testing; Lightning Measurements; Lightning and Surge Theory; Natural Lightning; Operating Experience; Protection of Buildings and Persons; Rapid Circuit Breaker Reclosure; Shield; Transformers; Transmission. Each title is listed only once, and when in French or German, an English translation is included. In the Author Section, the name of each author is listed with a reference number to his work in the Subject Section.

Copies of the AIEE Lightning Reference Bibliography for 1936–49 (AIEE special publication *C-37*) may be ordered from the AIEE Order Department, 33 West 39th Street, New York 18, N. Y. Prices are 35 cents per copy to AIEE members; 70 cents per copy to nonmembers. Proper remittance should be included with orders.

AIEE Group Inspects 500-Kv Test Site

At the conclusion of the AIEE Transmission and Distribution Committee meeting at the William Penn Hotel in Pittsburgh, Pa., April 25, members of the committee were invited by the American Gas and Electric Service Corporation to inspect the 500-kv test site and facilities at Brilliant, Ohio, for studying corona and other features in the extra-high-voltage range. In the above group are some members of the committee, guests, visitors, and the field test men. In the right background are the three single-phase transformers stepping the test voltage up to 500 kv. The instrument measuring equipment is in shielded metal boxes on top of the transformer bushings. In the center background is a self-supported single-phase 350-kv lightning arrester and in the upper left is the observation booth where the measuring instruments are read remotely by telescope

Philadelphia Section Announces Prize Paper Contest Winners

The AIEE Philadelphia Section has announced the winners of its annual Prize Paper Contest. They are listed in the following, together with the group in which their papers were adjudged best.

Industry and General Applications

(First Award) Carl L. Schuck, General Electric Company, "A New High Interrupting Capacity Low-Voltage Power Fuse."

(Second Award) Louis W. Moxey, III, Keller Pike Company, "Power for the Small Factory."

Power

(First Award) Clement S. Schifreen, Philadelphia Electric Company, "Thermal Expansion Effects in Power Cables."

(Second Award) George W. McKenna, Philadelphia Electric Company, "Theory and Application of Transformer Differential Protection."

Science and Electronics

(First Award) D. Rogers Crosby, RCA Victor Division, Radio Corporation of America, "Survey of Radio-Frequency Resistors With Kilowatt Ratings."

Student Papers

(First Award) Wallis D. Bolton, Moore

School, University of Pennsylvania, "Introduction to Control by Means of Servomechanisms."

(Second Award) Francis Haney, Villanova College, "A New Approach to Television Transmission."

First prize winners presented their papers and received cash awards and certificates during the Philadelphia Section's Prize Paper Night program held on May 8, while second award winners were given certificates. Awards were made by G. B. Schleicher, Philadelphia Electric Company, Chairman of the Prize Papers Committee.

Shown at the speakers' table (background) during the Industrial Power Systems luncheon held during the recent AIEE Power Conference in Pittsburgh, Pa., are, left to right: H. G. Barnett, Vice-Chairman, Industrial Power Systems Committee; S. A. Warner, Secretary, Industrial Power Systems Committee; W. A. Mosteller, Session Chairman; B. M. Jones, General Chairman of conference; F. H. Schlough, Chairman, AIEE Pittsburgh Section; A. C. Monteith, AIEE Director; J. S. Gault, Chairman, Industrial Power Systems Committee; R. S. Gardner, Assistant to the AIEE Secretary; W. H. Osterle, representing E. Wild, Chairman of Systems Engineering Committee

Richland Section Holds Dinner and Student Papers Contest

The AIEE Richland (Wash.) Section initiated another of its long-range program plans when it recently conducted a student papers contest. The 1950 contest papers were presented at a meeting in Richland on April 21 by the electrical engineering students currently enrolled at the Washington State College, Pullman, Wash. Prior to the meeting, Engineering School Dean Royal D. Sloan, Professor O. E. Osburn, and student guests from Washington State College were entertained with a dinner at the Richland Desert Inn.

Dean Sloan, a member of American Society for Engineering Education, addressed the meeting on the subject of "Trends and Developments in Engineering Education." He described the present evolution in engineering training which provides for greater emphasis on the humanities, social sciences, and fundamentals of engineering; he also discussed the anticipated fluctuations in engineering school enrollments for the next decade.

Professor Osburn, head of the Electrical Engineering Department at Washington State College, introduced the students who were presenting papers to the meeting.

Undergraduate Stuart W. McElhenny, Spokane, Wash., discussed "The Mototrol" which provides stepless speed control of d-c motors in sizes up to ten horsepower by means of thyratron rectifiers with associated control devices. He included a report of extensive laboratory tests to explore the stable speed range, resultant load currents, and efficiencies to be expected.

Undergraduate Richard K. Gerlitz, Pullman, discussed "A Saturable Reactor Excitation Circuit for Ignitrons." Several methods to initiate and control the cathode arc in ignitron tubes were described. The prime emphasis was given to the discussion of the characteristics and operation of the saturable reactor excitation scheme and was supported by laboratory tests and investigations.

Undergraduate Charles G. Alger, Spokane, described "Scandinavian Practices in Power Generation, Transmission, and Transmission-Line Construction." The current Scandinavian electric power design and construction program based on shortages of certain materials and damage experiences during the past war were described and illustrated with slides. He covered the favorable geological situation which permits the power plants to be cut out of solid granite rock with very limited concrete work required to complete the plant. He also described the extensive use of carefully designed relatively slender 380,000-volt transmission line concrete towers which were erected at the point of usage due to the very rough terrain.

Graduate Norman Olmstead, Sheridan, Ill., presented a paper on "The Economics of Pumped Storage for Supplemental Hydro Power Purposes." He described several methods using off-peak power from remotely located plants to pump water into storage basins near load centers with resultant high load factor usage of plants and transmission lines. The reduction of water going over the spillways was emphasized, together with the advantages derived from peaking power generated from stored water close to the load center. He described the American experience gained at the Rocky River (Conn.) plant, Lake George (Wis.) Meade plant, and the Big Thompson (Colo.) plant. The discussion also included a broad outline method whereby limited work would modify Grand Coulee irrigation pumps and Lake Chelan to create pumped storage for electric power generation.

The AIEE Richland Section plans to hold a student papers contest each year as a permanent program feature. The neighboring engineering schools will be invited to participate and appropriate prizes will be awarded. These contests will be held to encourage student electrical engineers to develop wider interests and acquaintances with current engineering practices concurrently with their study of basic theory.

First Power Conference Held in Pittsburgh

The AIEE Pittsburgh (Pa.) Section was host to the first Power Conference, sponsored by the AIEE Committees on Power Generation, Industrial Power Systems, and System Engineering, at the William Penn Hotel, Pittsburgh, April 19 and 20, 1950. The total attendance was 296, including 65 Student members from local colleges and universities.

Nineteen papers were presented at the four sessions; abstracts of most of these were published in the April issue of *Electrical Engineering*, pages 363–4. These conference papers will be published in their entirety later; copies may be had for $2.50 by writing to AIEE Headquarters, 33 West 39th Street, New York 18, N. Y.

T. E. Purcell, Director-at-Large, The American Society of Mechanical Engineers, and General Superintendent of Power Stations, Duquesne Light Company, was the speaker at the Power Generation luncheon on April 19; on the following day A. C. Monteith, National Director of AIEE and Vice-President of Westinghouse Electric Corporation, was the speaker at the Industrial Power Systems luncheon.

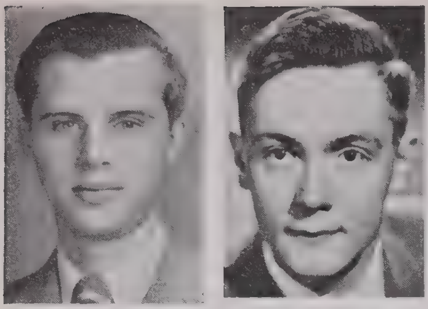
B. M. Jones, Planning Engineer of the Duquesne Light Company, was Chairman of the conference committee, which was composed of H. G. Barnett, J. A. Brooks, G. Calabrese, C. N. Clark, R. S. Gardner, J. S. Gault, L. N. Grier, H. R. Harris, W. A. Mosteller, F. H. Schlough, B. G. A. Skrotzki, and S. A. Warner.

Fortescue Fellowships Awarded for 1950-51

The Charles LeGeyt Fortescue Fellowship Committee has awarded two fellowships for graduate study in electrical engineering during the academic year 1950–51. One fellowship goes to Robert E. Horn, St. Louis, Mo., who is to receive the degree of Bachelor of Science in electrical engineering from Washington University in June; the other goes to Robert R. Johnson, Rockford, Ill., who is to receive the degree of Bachelor of Science in electrical engineering from the University of Wisconsin in June.

Mr. Horn is a member of Phi Eta Sigma, Pi Mu Epsilon, Tau Beta Pi, and Sigma Xi, and plans to do his graduate work at Washington University, with electronics as his major field.

Mr. Johnson is a member of Tau Beta Pi



Robert E. Horn (left) and Robert R. Johnson (right)

(President of Chapter, 1949–50), Eta Kappa Nu (President of Chapter, 1949–50), and Phi Eta Sigma. He was on the staff of the *Wisconsin Engineer* four years (Editor, 1949–50), and has been active in numerous other university organizations. He plans to do his graduate work at Yale University, with servomechanisms as his major field.

The Westinghouse Electric Corporation established a trust fund in 1939, as a memorial to Charles LeGeyt Fortescue, to provide for graduate fellowships in electrical engineering to be awarded by a committee of the AIEE.

Dr. Slepian Addresses AIEE Lima Subsection

With "The Engineer Can Be Wrong" as his subject, Dr. Joseph Slepian, Associate Director of the Westinghouse Research Laboratories, East Pittsburgh, Pa., addressed the Lima Subsection of the AIEE Dayton Section at a meeting on April 14, 1950. Present at the meeting were 43 AIEE members, 7 Student members from the Ohio Northern University Student Branch, and 15 guests.

In his address, Dr. Slepian reviewed Faraday's laws of induction and Maxwell's equations which were written to express mathematically Faraday's theories. He then presented some of the contradictory situations and inconsistencies which confront the electrical engineer who clings to generally accepted ideas and notions which have not been verified. He concluded his remarks with discussions of his electrical essays which have been presented in *Electrical Engineering*.

1950 Lamme Medal Nominations Due December 1

Special attention is directed to the fact that the names of Institute members who are considered eligible for the AIEE Lamme Medal, to be awarded early in 1951, may be submitted by any member in accordance with section 1 of article VI of the bylaws of the Lamme Medal Committee, as follows:

> The committee shall cause to be published in one or more issues of *Electrical Engineering*, or of its successors each year, preferably including the June issue, a statement regarding the Lamme Medal and an invitation for any member to present to the Secretary of the Institute by December 1, the name of a member as a nominee for the medal, accompanied by a statement of his "meritorious achievement" and the names of at least three engineers of standing who are familiar with the achievement.

Each nomination should give concisely the specific grounds upon which the award is proposed, and also a complete detailed statement of the achievements of the nominee, to enable the committee to determine its significance as compared with the achievements of other nominees. If the work of the nominee has been of a somewhat general character in co-operation with others, specific information should be given regarding his individual contributions. Names of endorsers should be given as specified in the foregoing quotation.

COMMITTEE ACTIVITIES

Editor's Note: This department has been created for the convenience of the various AIEE technical committees and will include brief news reports of committee activities. Items for this department, which should be as short as possible, should be forwarded to R. S. Gardner at AIEE Headquarters, 33 West 39th Street, New York 18, N. Y.

Industry Group

Committee on General Industry Applications. (*Kennard Pinder, Chairman; J. C. Fink, Vice-Chairman; V. O. Johnson, Secretary.*) Industrial processes in a mass production age offer numerous and diversified opportunities for equipment utilizing electric power. The majority work of this committee was organized in the summer of 1947, of sponsoring technical sessions and "Special Technical Conferences" where industrial electrical engineers can meet others in the same or allied fields and discuss electrical applications. For this purpose, the activities of the committee are carried on by the following subcommittees: rubber and plastics industries, pulp and paper industry, textile industry, machine tool industry, and materials handling industry. Conferences and technical sessions devoted to these individual industries were organized and have been reported in *Electrical Engineering*.

Additional subcommittees to cover other industries will be organized in the near future. This committee believes there is no better way to further engineering knowledge and bring the AIEE close to engineers working on industrial problems than to bring together in technical sessions and conferences a group of engineers with wide and varied experiences.

Subcommittee on Terminology and Nomenclature of Feedback-Control Systems Committee. (*S. W. Herwald, Chairman.*) This subcommittee has prepared and submitted to the main committee a report on its work. In this report it is stated that the need for universally accepted symbolism for feedback control systems is quite apparent to anyone working in the field. However, the present random usage of symbols is particularly confusing to those whose endeavors bring them into contact with just the application of feedback control systems. The theory of feedback control stems from many diversified fields. In the past decade the many military servomechanism applications have resulted in the introduction to the feedback control system field of engineers having communications backgrounds who have brought into this work the symbolism common to that branch of engineering. If an acceptable unified symbolism can be adopted and used, the many diversified fields can be united in common understanding, regardless of the background of the individuals. It is most important in reviewing the symbols proposed that one decide only whether they are acceptable rather than whether they are the best from the individual standpoint. It is only by compromising that standard nomenclature can be obtained and it is believed the benefits far outweigh the compromise any one individual may have to make.

In establishing standard symbols for feedback controls, there are two types of symbols which must be considered: the diagrammatic symbols and the letter symbols. It was thought in this committee that work on both of these could best be initiated by evolving letter symbols, names, and diagrammatic symbols involved in fundamental feedback control systems. In evolving the recommended symbolism on feedback control, it must be recognized that there are many groups having diversified interests which must be resolved. In arriving at the recommended symbolism, there was much effort put forth in many committee meetings over the past year, both in The American Society of Mechanical Engineers and the AIEE.

Details of the complete report of the subcommittee may be incorporated in a future conference paper but the committee will continue its work to define controversial terms, and so forth.

Power Group

Committee on Protective Devices. (*W. J. Rudge, Chairman; H. R. Stewart, Vice-Chairman; A. A. Johnson, Secretary.*) The activities of this committee are carried on largely by the subcommittees.

Fault Limiting Devices Subcommittee. Application guides covering the grounding of synchronous generating systems, the method of grounding transmission systems, and the application of ground fault neutralizers have been completed.

Lightning Protective Devices Subcommittee. The activities of this subcommittee have been directed toward the co-ordination and unification of information relating to: performance characteristics; testing standards; and applications of various types of lightning protective devices.

Co-ordination of Insulation Subcommittee. This subcommittee was set up to deal with problems of insulation co-ordination which come within the scope of the Protective Devices Committee.

Committee on Transformers. (*J. B. Hodtum, Chairman; F. J. Vogel, Vice-Chairman; M. K. Brown, Secretary.*) The subcommittee handling instrument transformers has completed a "Guide for Grounding of Instrument Transformer Secondary Circuits and Cases," which will be issued shortly as a revision of ASA (American Standards Association) *C57.37*. The subcommittee working on "Operating Guides for Regulators" has submitted technical paper 49-228, which is now in the hands of the

AIEE Standards Committee to be issued as a revision of ASA *C57.35*. The subcommittee working on the "Method of Making Temperature Tests on Transformers" has submitted technical paper 50-99. The work of this subcommittee will continue with the object of completely revising ASA Standards *C57.22.100* through *22.105*.

Two new subcommittees have been established, one of which will conduct a study on "Hot-Spot Temperature Rise of Class *B* Reactors." The other new subcommittee is working on the permissible maximum oil temperature of transformers in service. This latter subject is a study to determine whether it is permissible to operate sealed-type transformers in excess of the 100-degree-centigrade limitation in the present guide, *C57.32*.

The Transformer Committee is sponsoring two sessions on June 14 during the AIEE Summer and Pacific General Meeting in Pasadena, Calif.

Lightning Protective Devices Subcommittee of Committee on Protective Devices. (*E. H. Yonkers, Chairman.*) The Report on Standard for Valve and Expulsion-Type Lightning Arresters has been published as AIEE *28A*, February 1950. It combines AIEE Standards *28* (American Standards Association *C62.1*), *24*, and *47* in a proposed revision. This report is available at AIEE Headquarters, 33 West 39th Street, New York, N. Y., and comments will be welcomed by the Protective Devices Committee. This report is the result of five years of work on the part of the working group under Chairman F. M. Defandorf. A discussion of the report was presented at the Winter General Meeting by H. R. Stewart and Mr. Defandorf.

A Substation Lightning Arrester Application Guide is in preparation by a group under Chairman H. A. Cornelius. It will attempt to evaluate all the factors to be considered in arrester application. In particular, the question of safe spacing between arrester and transformer or length of connections is being studied under a joint project with the Transmission and Distribution Committee. The analogue computer and transient analyzer are of major importance in studying the full range of circuit distances that can be sampled only in a limited way by full-scale tests.

Science and Electronics Group

Committee on Instruments and Measurements. (*W. R. Clark, Chairman; J. H. Miller, Vice-Chairman (East); J. E. Hobson, Vice-Chairman (West); J. G. Reid, Jr., (Secretary.)* The following subcommittees have been formed recently.

Subcommittee on Industrial Spectroscopy, under chairmanship of J. H. Enns, will handle matters relating to design and characteristics of instruments and measurements pertinent to the field of industrial spectroscopy. It will promote technical sessions covering new or improved practices and determine standards and definitions for this particular field. The final scope will be determined when the subcommittee becomes better organized and has its first meeting.

Subcommittee on Master Test Code for Power Measurements, under chairmanship of C. J. Zeller, will draft a Master Test Code for Power Measurements, as required throughout the field of electrical engineering. It is intended that the code be similar in construction to the Master Test Code for Resistance Measurements and the Master Test Code for Temperature Measurements, which recently were completed by the main committee.

AIEE PERSONALITIES.....

A. H. Timmerman (A '03, F '12, Member for Life), Vice-President and Director, Wagner Electric Corporation, St. Louis, Mo., has retired after more than 50 years service with the company. Mr. Timmerman was born in New York, N. Y., on May 1, 1871, and was educated at Cornell University, where he received the degrees of Bachelor of Science in 1891, Mechanical Engineer in Electrical Engineering in 1892, and Master of Mechanical Engineering in 1893. Mr. Timmerman was an instructor in electrical engineering at Washington University, St. Louis, from 1893 to 1894, and a Professor of Physics in charge of electrical engineering at the School of Mines and Metallurgy of the University of Missouri, Columbia, from 1894 to 1899. He first became associated with the Wagner Electric Corporation in 1899 as Assistant Superintendent, and in 1908 was made Chief Engineer. In 1925, he became Vice-President and a Director of the company. Mr. Timmerman has served the Institute as a member of the following committees: Industrial and Domestic Power (1919–20); Standards (1919–22); and Electric Machinery (1924–25). **G. A. Waters** (A '09, F '21, Member for Life), Vice-President in charge of manufacturing, succeeds Mr. Timmerman as a Director of the company. Mr. Waters joined the company in 1909 and was made Manager of the Transformer Engineering Division a year later. In 1918 he was made Assistant Chief Engineer, and in 1943, he became Chief Engineer. He was elected Vice-President in charge of manufacturing, the position he still occupies, in 1946. **V. W. Bergenthal** (A '01, Member for Life), Director, and **E. B. Meissner** (A '16, M '45), President and General Manager, St. Louis (Mo.) Car Company, have been re-elected Directors of the Wagner Electric Corporation.

D. B. Sinclair (M '45), Assistant Chief Engineer, General Radio Company, Cambridge, Mass., has been appointed Chief Engineer. Dr. Sinclair was educated at the University of Manitoba and Massachusetts Institute of Technology, where he received the degree of Doctor of Science in 1935. From 1932 to 1935, he was a Research Assistant and later a Research Associate at the Massachusetts Institute of Technology, Cambridge. He has been with the General Radio Company since 1936, except for the period during World War II when he worked in the Countermeasures Division and the Guided Missiles Division of the National Defense Research Council, receiving the President's Certificate of Merit for outstanding services. Dr. Sinclair is a Fellow, Treasurer, and a Director of the Institute of Radio Engineers and is a member of Sigma Xi.

L. C. Holmes (A '31, M '43), Senior Electrical Engineer, Research Laboratory, Stromberg-Carlson Company, Rochester, N. Y., has been made Associate Director of Research. Mr. Holmes is a graduate of Rensselaer Polytechnic Institute where he taught for 18 years following his graduation in 1925. He holds the degrees of Electrical Engineer and Master of Electrical Engineering. He is well known in the field of magnetic sound recording. Mr. Holmes is Chairman of the Rochester (N. Y.) Section Membership Committee and is a member of the Radio Manufacturers Association, the American Standards Association, the Institute of Radio Engineers, the Acoustical Society of America, and Sigma Xi.

G. C. Harvey (A '33, M '44), Assistant Section Engineer, Ballast Engineering Division, General Electric Company, Fort Wayne, Ind., has been appointed Division Engineer of the Ballast Engineering Division. Mr. Harvey was graduated from Ohio State University in 1931 and joined the General Electric Company the same year. In 1936 he was assigned to the engineering section of the Fractional Horsepower Motor Divisions at Fort Wayne, and in 1945 was transferred to a similar position in the Decatur, Ind., plant. He returned to Fort Wayne two years later as Assistant Section Engineer.

A. C. Hall (M '44), Associate Professor of Electrical Engineering, Massachusetts Institute of Technology, Cambridge, has been appointed Associate Technical Director, Research Laboratories, Bendix Aviation Corporation, Detroit, Mich. Dr. Hall has been with the Massachusetts Institute of Technology for 13 years and is one of the country's foremost authorities on servomechanics. He has developed a flight simulator and a control system for the first guided missile used by the United States Navy. Dr. Hall is a member of the Institute of Radio Engineers.

Chester Lichtenberg (A '05, F '49), retired, has been elected President of the Department of Indiana, Reserve Officers Association of the United States. Colonel Lichtenberg is also serving as the National Director of the Indiana Society of Professional Engineers and as the Executive Director of the Fort Wayne and Allen County, Ind., Civil Defense Council. He was retired by the General Electric Company last year after more than 42 years of service.

E. W. Boehne (A '29, F '43), Associate Professor and Director, Co-operative Courses in Electrical Engineering, Massachusetts Institute of Technology, Cambridge, has been promoted to the rank of full Professor.

Dr. Boehne is serving the Institute as a Student Branch Counselor and as a member of the Research Committee. **Alexander Kusko** (A '43), Instructor in Electrical Engineering, has been promoted to the rank of Assistant Professor.

J. W. Barker (M '26, F '30), President, Research Corporation, New York, N. Y., has been appointed a member of the advisory committee of the Chase National Bank's Grand Central Branch. Mr. Barker is serving the Institute as a member of the Research Committee, the Council of the American Association for the Advancement of Science, the Charles LeGeyt Fortescue Fellowship Committee, and the Engineering Foundation Board.

E. P. Nelson (A '27, M '45), Consulting Engineer, Mt. Vernon, N. Y., has joined Designers for Industry, Inc., Cleveland, Ohio, as Vice-President in charge of Metropolitan New York and the surrounding area. Mr. Nelson, graduate of Harvard University in 1924 in both electrical engineering and business administration, is a member of the American Society of Naval Engineers and the Society of Naval Architects and Marine Engineers.

E. E. Folsom, Jr. (A '46), Assistant Manager, Home Laundry Equipment Division, General Electric Company, Trenton, N. J., has been appointed Manager of the division. Mr. Folsom joined the General Electric Company in 1928 and held the positions of production clerk, assistant engineer, and quality control engineer prior to his appointment as Assistant Manager of the Home Laundry Equipment Division.

F. I. Biggs (A '50), Section Engineer, A-C Generators, Elliott Company, Jeanette, Pa., has been named Division Engineer for the Ridgway Works of the company. Mr. Biggs has been with the Elliott Company since 1933, when he was graduated with an electrical engineering degree from Cornell University. He has successively held the positions of sales engineer and product engineer before his present appointment.

H. A. Frey (A '28, M '43), Chief Development Engineer, Locke Insulator Corporation, Inc., Baltimore, Md., has been appointed Assistant Manager of the Engineering Department. Mr. Frey is a graduate of The Johns Hopkins University and has been associated with the Locke Insulator Corporation since 1926. He is a member of the Engineers Club of Baltimore (Md.) and Kappa Alpha.

A. C. Allen (A '40), Manager, Memphis (Tenn.) Sales Office, Wagner Electric Corporation, will remain at Memphis as Branch Manager of the southern portion of the sales territory served by the St. Louis, Mo., electrical division of the corporation, which has been set up as a separate unit with headquarters in Memphis and a sales office in New Orleans, La.

F. B. Silsbee (A '13, F '42, Member for Life), Chief, Electricity and Optics Division, National Bureau of Standards, Washington, D. C., has been elected President of the Washington Academy of Sciences. The academy, which was founded in 1898, acts as the federal head of 19 affiliated scientific and engineering societies in the Washington area.

E. V. DeBlieux (A '34, F '49), Assistant to Division Engineer, Power Transformer Engineering Division, General Electric Company, Pittsfield, Mass., has been appointed Division Engineer, High-Voltage Bushing Engineering Division. Mr. DeBlieux is Chairman of the Pittsfield Section Transfers Committee.

G. A. Fleming (M '39, F '49), Electrical Engineer, Power Marketing, Region II (Sacramento, Calif.), Bureau of Reclamation, Department of the Interior, has been assigned to the advance reconnaissance group of the Bureau of Reclamation technologists, who will study the feasibility of expanding the hydroelectric development of Korea.

A. E. Beattie (M '47), Assistant Superintendent of Engineering, Gulf States Utilities Company, Beaumont, Tex., has been appointed Superintendent of Planning. Mr. Beattie is a member of the AIEE Committee on Transmission and Distribution. **R. W. Sherwood** (A '46), Design Engineer for the company, has been appointed Superintendent of Design.

K. A. Vaughan (A '47), Manager, Field Engineering, Gould Storage Battery Corporation, Trenton, N. J., has been advanced to the newly created position of Manager of Sales Engineering. Mr. Vaughan has been with the Gould Storage Battery Corporation since 1928 and was appointed Field Engineering Manager in 1945.

O. V. Tally (M '44), Manager, St. Louis (Mo.) District, Allis-Chalmers Manufacturing Company, has been named Manager of the Midwest region. **B. G. Witty** (A '40, M '46), Sales Representative, Chicago (Ill.) Office, succeeds Mr. Tally as manager of the St. Louis District.

George Hamburger, III (A '44, M '48), District Manager, Copperweld Steel Company, St. Louis, Mo., has been appointed Manager of Communication Sales covering the entire United States. He is a member of the Society of American Military Engineers and the Independent Telephone Pioneers Association.

L. H. Matthes (A '31), Apparatus Department, General Electric Company, Newark, N. J., has been named Assistant Manager of Sales, Large Motor and Generator Divisions. Mr. Matthes has been with the General Electric Company since 1922.

C. E. Burke (M '49), Manager, Distribution Transformer Sales Division, Transformer and Allied Product Divisions, General Electric Company, Pittsfield, Mass., has been named Manager of Sales, Speciality Transformer and Ballast Divisions, Fort Wayne, Ind.

R. B. Moore (A '45), Application Engineer, General Electric Company, Schenectady, N. Y., has been appointed Manager of the Mining Division of the General Electric Company's Industrial Engineering Divisions. Mr. Moore has been with the company since 1940.

J. S. Morgan (A '39, M '46), Engineer-in-Charge of Sales, Switchgear and Control Sections, Allis-Chalmers Manufacturing Company, Milwaukee, Wis., has been named Manager of the Switchgear Section. Mr. Morgan has been associated with Allis-Chalmers since 1935 and was made Engineer-in-Charge of sales in 1947. He is a member of the Industrial Power Systems Committee and a member of the Engineers' Society of Milwaukee.

H. B. Hansteen (A '26, M '43), Professor of Electrical Engineering, Cornell University, has changed his affiliation to The College of the City of New York (N. Y.) as Professor of Electrical Engineering. Previous to his $3^1/_2$-year stay at Cornell University, Professor Hansteen had been associated with The College of the City of New York for nine years. From 1948 to 1949 he was Visiting Senior Power Engineer at the Brookhaven National Laboratory.

F. H. Clark (A '45), Manager, Small A-C Control Sales Department, Westinghouse Electric Corporation, Beaver, Pa., has been named Sales Manager for the Standard Control Division of the company in Beaver.

W. J. Seeley (A '19, M '28, F '45), Chairman of the Department of Electrical Engineering, Duke University, has begun a sabbatical leave-of-absence to continue his duties as Vice-President representing District 4.

L. L. Crump (M '32, F '42), Vice-President, James R. Kearney Corporation, St. Louis, Mo., has been appointed Sales-Engineering Co-ordinator.

C. L. Emerson (M '20, F '33), Vice-President and Dean, School of Engineering, Georgia Institute of Technology; **C. G. Roush** (A '37, M '41), Manager, Westinghouse Electric Corporation, Kansas City, Mo.; and **E. N. Holm** (A '47), Valuation Engineer, Sacramento (Calif.) Municipal Utility District, have been named as Vice-Presidents of the National Society of Professional Engineers for 1950–51.

L. L. Burns, Jr. (A '44), Research Engineer, RCA Laboratories, Radio Corporation of America, Princeton, N. J., has been presented with an RCA award for outstanding accomplishment in research in electronics during 1949.

W. F. Strong (A '41, M '48), Application Engineer, Industrial Engineering Division, General Electric Company, Schenectady, N. Y., has been transferred to the company's Dallas (Tex.) Office as an application engineer for the Southwestern District.

E. B. Doll (A '38, M '47), Chief Engineer, North American Philips Company, Dobbs

Ferry, N. Y., has joined the engineering staff of the Stanford (Calif.) Research Institute. Dr. Doll was head physicist for the Bureau of Ordnance, United States Navy, Pearl Harbor, Hawaii, during part of World War II.

R. G. Lorraine (A '29, M '36), Central Station Engineering Division, General Electric Company, Schenectady, N. Y., has been appointed head of a new project in the Knolls Atomic Power Laboratory, Atomic Energy Commission, General Electric Research Laboratory, Schenectady, N. Y. Mr. Lorraine is a member of the Committee on Nucleonics.

I. K. Dortort (A '29, M '38), Engineer, Electronic Section, Electrical Department, Allis-Chalmers Manufacturing Company, Milwaukee, Wis., has accepted an engineering position with the Rectifier Division of the I-T-E Circuit Breaker Company, Philadelphia, Pa. Mr. Dortort is Chairman of the Electronic Power Converter Circuits Subcommittee.

W. F. Greenwood (A '48), Works Manager, Los Angeles and San Francisco Branches, Trumbull Electric Manufacturing Company, has been appointed Manager of Industrial Sales for Telechron, Inc., Ashland, Mass.

D. H. Jones (A '38), Sales Manager, American Transformer Company, Newark, N. J., has been appointed General Sales Manager, Coating and Fibron Divisions, Irvington Varnish and Insulator Company, Irvington, N. J.

M. I. Alimansky (A '45), Assistant to the Manager, Transformer and Allied Products Divisions, General Electric Company, Pittsfield, Mass., has been appointed Assistant Manager of the divisions.

A. A. Schuhler (A '19, M '27), Branch Manager, Sperti-Faraday Inc., New York, N. Y., has accepted a position as Sales Engineer of the Eastern District, Edwards and Company, New York, N. Y.

J. A. Derry (M '49), Co-ordinator of Special Assignments, Division of Production, United States Atomic Energy Commission, Washington, D. C., has been appointed Executive Officer of the division.

F. D. McGuire, Jr. (A '49), Engineer, Allis-Chalmers Manufacturing Company, Milwaukee, Wis., has been named sales representative, General Machinery Division, Midwest and Central regions, for the company.

R. W. Kunkle (A '49), Sales Manager, Pittsburgh, Pa., District, A. B. Chance Company, Centralia, Mo., has been appointed Manager of Anchor Sales. Mr. Kunkle joined the company in 1948 as a sales engineer.

OBITUARY

William Keith McAfee (A '16, M '21), Chairman of the Board, Universal-Rundle Corporation, Redlands, Calif., died February 2, 1950. Born on January 26, 1893, in Pittsburgh, Pa., Mr. McAfee was graduated from the University of Pennsylvania with a Bachelor of Science degree in electrical engineering in 1915. He began his career with the Westinghouse Electric and Manufacturing Company (now the Westinghouse Electric Corporation) in 1915, remaining with the company until 1920 when he became associated with the Pennsylvania Railroad Company. In 1922, Mr. McAfee became Chief Engineer of the Universal Sanitary Manufacturing Company, and was later successively elected Vice-President, President, and, in 1947, Chairman of the Board. In 1948, the Universal Sanitary Manufacturing Company merged with the Rundle Company, becoming the Universal-Rundle Corporation, of which Mr. McAfee was Board Chairman. He was a Fellow of the American Association for the Advancement of Science and of the American Ceramic Society. He was also on the Board of Directors of the National Association of Manufacturers and the California Manufacturers Association.

Ray O. Draper (A '45), General Foreman, Maintenance Department, Ford Motor Company, Buffalo, N. Y., died December 26, 1949. Mr. Draper was born in Buffalo on January 10, 1894, and studied electrical engineering with the International Correspondence School and chemical engineering at the University of Buffalo. From 1916 to 1925, Mr. Draper was successively employed by three Buffalo concerns; the Buffalo General Electric Company, the Donner Steel Company, and the National Aniline Company. In 1925 he took the position of electrical engineer in charge of construction and maintenance with the General Chemical Company of Buffalo, N. Y., and Chicago, Ill. Mr. Draper worked in a similar capacity with the Ford Motor Company, Buffalo, and the General Motors Corporation, Buffalo, from 1931 to 1938. From 1938 to 1944 he was with the Durez Plastics and Chemical Company, Tonawanda, N. Y., and in 1944 became electrical engineer in charge of maintenance, General Cable Corporation, Perth Amboy, N. J. In 1946 he became General Foreman in the Maintenance Department of the Ford Motor Company.

Walter E. Poor (A '15), Chairman of the Board, Sylvania Electric Products, Inc., New York, N. Y., died April 4, 1950. Mr. Poor was born on November 23, 1885, in Salem, Mass., and received the degree of Electrical Engineer from the Massachusetts Institute of Technology in 1908. After working one year as electrical engineer for the Boston (Mass.) Elevated Railway, Mr. Poor joined his brothers in the manufacture of electric lamps at Danvers, Mass. In 1911, he accepted an electrical engineering position with the Hygrade Lamp Company, Danvers (predecessor of Sylvania Electric Products), later becoming Vice-President and General Manager. In 1940 he was made Executive Vice-President, in 1943 he was elected President, and in 1946 he became Chairman of the Board. He was a member the Institute of Radio Engineers.

Hamaz H. Kalantar (M '42), Electrical Engineer, United Engineers and Constructors, Inc., Philadelphia, Pa., died recently. Born in Tiflis, Armenia, on July 14, 1882, Mr. Kalantar was educated at the Russian Technical College and the University of Dresden (Germany), where he received the degree of Electrical Engineer and Mechanical Engineer in 1905. From 1905 to 1910, he worked for concerns in Germany, Switzerland, and Russian Baku. In 1910, Mr. Kalantar accepted a position with the Westinghouse Electrical and Manufacturing Company and from 1912 to 1917 was an electrical designer for the Westinghouse Church Kerr and Company. From 1917 to 1919, he was with the Air Nitrate Corporation, and from 1919 to 1925 he was employed as an electrical designing engineer for the Dwight P. Robinson Company. In successive years, Mr. Kalantar worked for various electrical concerns, including the Amtorg Trading Corporation, the American Cyanamid Company, the Electric Management and Engineering Corporation, E. B. Badger and Sons, and United Engineers and Constructors, Inc.

William L. Kaehni (M '44), Senior Partner, Kaehni Brothers, Cleveland, Ohio, died January 27, 1950. Mr. Kaehni was born July 4, 1894, in Cleveland, and in 1917 he was graduated with an Electrical Engineering degree from the Case School of Applied Science (now Case Institute of Technology). During World War I, he served as a first lieutenant in the Army of the United States. From 1918 to 1925, Mr. Kaehni was with the American Telephone and Telegraph Company, Cleveland, as transmission engineer and instructor. In this capacity he operated the first Bell loud-speaker installations in that part of the country. After leaving the employ of the American Telephone and Telegraph Company, Mr. Kaehni worked exclusively with the research laboratory established in partnership with his brother five years previously. Mr. Kaehni was consulting engineer for various companies and held patents pertaining to radio, stroboscopic lighting effects, an electron compass, and navigational instruments.

Carl George Archibald (A '37), Engineering and Service Department, Westinghouse Electric Corporation, Buffalo, N. Y., died April 12, 1950. Mr. Archibald was born in Eagleville, Ohio, on February 6, 1904, and was graduated from Oregon State College with a Bachelor of Science degree in electrical engineering in 1927. Mr. Archibald had been associated with the Westinghouse Electric Corporation since 1927, when he was an engineering student in their test program. He successively held the positions of laboratory assistant, Trafford High Voltage Laboratory; engineering assistant, Miscellaneous Engineering Department; sales engineer; central station engineer; and factory representative, Engineering and Service Department.

Richard M. Boykin (A '13, M '20, Member for Life), Ebasco Services, Inc., New York, N. Y., died January 29, 1950. Mr. Boykin was born in Sumter County, S. C., on April 13, 1878, and was graduated from Alabama Polytechnic Institute in 1897 with the degree of Bachelor of Science in electrical engineering. From 1911 to 1916, Mr. Boykin worked as an electrical engineer for the Washington Oregon Corporation and in 1917 became Chief Engineer for the North Coast Power Company. Also in 1917, he was named Vice-President and General Manager of the North Coast Power Company. In 1924, Mr. Boykin became Manager, Central District, Puget Sound Power and Light Company, Seattle, Wash., and in 1930, he joined the Electric Bond and Share Company, New York, of which Ebasco Services, Inc., is a subsidiary.

Walter Kent (M '44, Member for Life), retired, died February 10, 1950. Born on May 10, 1878, in LaGrange County, Ind., Mr. Kent was educated at Purdue University, receiving the degree of Bachelor of Science in electrical engineering in 1904. Mr. Kent had been associated with the General Electric Company, Fort Wayne, Ind., for 43 years until his retirement in 1947. He started with the company as a student engineer in 1904, and after holding the positions of engineer in charge of insulating materials and engineer in charge of final inspection for d-c apparatus, Mr. Kent rose to the position of design engineer, which was the position he held at the time of his retirement.

MEMBERSHIP • • • •

Recommended for Transfer

The Board of Examiners at its meeting of April 20, 1950, recommended the following members for transfer to the grade of membership indicated. Any objections to these transfers should be filed at once with the Secretary of the Institute. A statement of valid reasons for such objections must be furnished and will be treated as confidential.

To Grade of Fellow

Abbott, T. A., executive director, engg. research dept., Standard Oil Co. (Indiana), Chicago, Ill.
Anderson, A. S., elec. engr., Ebasco Services, Inc., New York, N. Y.
Andrews, F. E., elec. trans. & dist. design engr., Public Service Co. of Northern Illinois, Chicago, Ill.
Ballenger, W. M., district mgr., engg. div., General Electric Co., Chicago, Ill.
Boorzhinsky, N. P., elec. engr., Moloney Electric Co., St. Louis, Mo.
Burger, E. J., vice-pres.; director & div. mgr., The Ohio Public Service Co., Warren, Ohio
Jalonack, H. M., mgr., marketing & promotional service div., General Electric Co., Pittsfield, Mass.
Kappel, F. R., vice-pres., American Tel. & Tel. Co., New York, N. Y.
Kidder, A. H., asst. engr., chg. special investigation & testing div., Philadelphia Electric Co., Philadelphia, Pa.
O'Connor, R. R., transmission engr., Illinois Bell Telephone Co., Chicago, Ill.
Rudenberg, R., Gordon McKay prof. of elec. engg., Harvard Univ., Cambridge, Mass.
Shepherd, J. O., plant extensions engr., Southern Bell Tel. & Tel. Co., Atlanta, Ga.
Snyder, C. E., chief engr., Packard Electric Co., Ltd., St. Catharines, Ontario, Canada
13 to grade of Fellow

To Grade of Member

Anderson, D. W., supervising substation engr., Northern Indiana Public Service Co., Hammond, Ind.
Babcock, C. W., field engr., General Electric Co., Denver, Colo.
Bundy, O. M., consulting engr., The Clark Controller Co., Cleveland, Ohio
Cepelak, J., elec. lab. foreman, Scovill Mfg. Co., Waterbury, Conn.
Clark, M. E., materials & practices engr., New England Tel. & Tel. Co., Boston, Mass.
Cogburn, C. W., asst. engr., Florida Power & Light Co., Miami, Fla.
Craddock, J. M., asst. mgr., Humble Oil & Refining Co., Houston, Tex.
Davidson, G. M., elec. engr., Naval Ordnance Lab., White Oak, Md.
Dyer, C. E., supt., retail div., Knoxville Power Co., Alcoa, Tenn.
Edge, D. R., government sales representative, Graybar Electric Co., Washington, D. C.
Estrin, M., aeronautical research scientist, National Advisory Comm. for Aeronautics, Cleveland, Ohio
Farmer, J. L., street lighting engr., Oklahoma Gas & Elec. Co., Oklahoma City, Okla.
Feigal, R. S., research engr., Minneapolis Honeywell Regulator Co., Minneapolis, Minn.
Field, W. J., engr., Engineering Research Associates Inc., St. Paul, Minn.
Fischer, P. M., elec. engr., Cutler-Hammer, Inc., Milwaukee, Wis.
Fletcher, K. V., sales engr., General Electric Co., Phoenix, Ariz.
Freeland, M. W., field construction engr., Rural Electrification Administration, Ft. Dodge, Iowa
Fuller, R. G., mgr. & chief engr., Pekin Syndicate, Ltd., Shanghai, China
Gatzke, I. H., engr., Bureau of Aeronautics, Navy Dept., Washington, D. C.
Gibbs, J. T., chief engr., Volunteer Electric Cooperative, Decatur, Tenn.
Haas, P. A., distribution engr., Board of Public Utilities, Kansas City, Kans.
Hamilton, R. A., mgr., induction motor section, Canadian General Electric Co., Ltd., Toronto, Ontario, Canada
Hamm, C. T., elec. design supervisor, San Francisco Naval Shipyard, San Francisco, Calif.
Hasselbacher, H. H., genl. telegraph supt., Burlington Lines, Chicago, Ill.
Hermach, F. L., elec. engr., National Bureau of Standards, Washington, D. C.
Johnson, P. H., elec. engr., Public Service Co. of Colorado, Denver, Colo.
Johnston, C. J., area engr., Northwestern Bell Telephone Co., Fargo, N. Dak.
Jones, E. W., assoc. prof. of elec. engg., Illinois Institute of Technology, Chicago, Ill.
Jones, E. R., asst. supt., Hawthorn Station, Kansas City Pr. & Lt. Co., Kansas City, Mo.
Kadletz, J. A., supervising engr., General Electric Co., Schenectady, N. Y.
Keiffer, M. H., elec. & construction engr., Manheim, Pa.
Kellway, B. J., elec. engg. instructor, Manhattan College, N. Y., N. Y.
King, E. F., development engr., A. B. Chance Co., Centralia, Mo.
Kingsbury, J. W., div. plant engr., American Tel. & Tel. Co., Philadelphia, Pa.
Kleinberger, R. C., consulting engr., White Plains, N. Y.
Kurch, P. G., engr., chg. of test, Pennsylvania Transformer Co., Canonsburg, Pa.
Lansch, J., elec. engr. & squad leader, Ebasco Services, Inc., New York, N. Y.
Lauritsen, C. N., div. operating supt., Public Service Co. of Northern Illinois, Joliet, Ill.
Leeds, D. A., special engr., Northern Indiana Public Service Co., Hammond, Ind.
Lovelady, M. H., asst. chief engr., Central Pr. & Lt. Co., Corpus Christi, Tex.
Lundgren, C. W., elec. engr., Northern Indiana Public Service Co., Gary, Ind.
McAleer, G. H., supervisor substation dept., Commonwealth Edison Co., Chicago, Ill.
McCormack, J. B., elec. engr., Harza Engineering Co., Chicago, Ill.
McNair, J. S., supt. production plant maint. & constr. dept., The Washington Water Power Co., Spokane, Wash.
Middough, W. V., elec. engr., The Osborn Engg. Co., Cleveland, Ohio
Mika, H. S., physicist, process dev., U. S. Rubber Co., Detroit, Mich.
Needham, G. H., asst. engr., New Jersey Bell Telephone Co., Newark, N. J.
Nodder, W. R., manufacturer's repr., Geo. E. Honn Co., San Francisco, Calif.
Page, J. C., elec. engr., General Electric Co., Schenectady, N. Y.
Phillips, V. E., elec. engr., General Electric Co., Philadelphia, Pa.
Plank, H. H., vice-pres., engg. & operation, Delaware Pr. & Lt. Co., Wilmington, Del.
Post, H. L., design engr., Humble Oil & Refining Co., Baytown, Tex.
Pradhan, S. R., relieving supt., The Tata Power Co., Ltd., Kolaba, India
Pritchett, W. S., elec. engg. lecturer, Univ. of California, Berkeley, Calif.
Profitt, A. H., project engr., system planning sec., Tennessee Valley Authority, Chattanooga, Tenn.
Puette, R. L., vice-pres., chg. production, The Clark Controller Co., Cleveland, Ohio
Razovsky, A. M., elec. engr., IV, Tennessee Valley Authority, Chattanooga, Tenn.
Rickman, A. A., elec. engr., vice-pres., E. C. Ernst, Inc., Washington, D. C.
Roberts, N. J., genl. industrial engr., Ohio Public Service Co., Cleveland, Ohio
Sample, B., supervisor, Houston Lighting & Power Co., Houston, Tex.
Schmitt, D. J., elec. engr., General Electric Co., Seattle, Wash.
Schooley, C. E., transmission engr., long lines dept., American Tel. & Tel. Co., New York, N. Y.
Schutz, T., exchange engr., Southwestern Bell Tel. Co., Houston, Tex.
Sexauer, B. H., elec. engr., Ebasco Services, Inc., New York, N. Y.
Shackelford, C. L., design engr., Westinghouse Elec. Corp., Bloomfield, N. J.
Skina, F. A., production chief, substation design, Bonneville Power Administration, Portland, Oreg.
Smith, L. E., elec. engr., The Toledo Edison Co., Toledo, Ohio
Smith, W. M., circuit engr., Gray Research & Development Co., Hartford, Conn.
Sorenson, H., asst. underground engr., Wisconsin Elec. Pr. Co., Milwaukee, Wis.
Thompson, D. L., supervisory engr., Northern Indiana Public Service Co., Hammond, Ind.
Tizian, S. L., consulting engr., New York, N. Y. & Newark, N. J.
Troup, R. J., engr., relay test section, Northern Indiana Public Service Co., Hammond, Ind.
Tusin, A. S., resident engr., Reliance Electric & Engg. Co., Ashtabula, Ohio
Weaver, H. E., engr., laboratory tests, Public Service Co. of Northern Illinois, Maywood, Ill.
Williams, J. R., electronic scientist, Naval Research Lab., Washington, D. C.
Wood, R. H., designer, Georgia Power Co., Atlanta, Ga.
76 to grade of Member

Applications for Election

Applications for admission or re-election to Institute membership, in the grades of Fellow and Member, have been received from the following candidates, and any member objecting to election should so notify the Secretary before June 25, 1950, or August 25, 1950, if the applicant resides outside of the United States, Canada, or Mexico.

To Grade of Fellow

Uehling, F. F., Uehling Instrument Co., Paterson, N. J.

1 to grade of Fellow

To Grade of Member

Bader, R. D., Consolidated Gas, Elec. Light & Power Co., Baltimore, Md.
Baird, L. L., General Elec. Co., Philadelphia, Pa.
Banning, F. D., Building Code Revision Comm., Administrator City of Miami, Fla.
Bark, R. S., Univ. of Washington School of Medicine, Seattle, Wash.
Barney, G., Stone & Webster Engg. Corp., Boston, Mass.
Bensing, W. G., Automatic Elec. Co., Chicago, Ill.
Blosser, H. G., Union Switch & Signal Co., Pittsburgh, Pa.
Borghesani, W. H., Stone & Webster Engg. Corp., Boston, Mass.
Bozorth, R. M., Bell Tel. Labs., Murray Hill, N. J.
Carmichael, E. T. (re-election), Public Service Production Co., Newark, N. J.
Crandall, H. V., Consumers Power Co., Flint, Mich.
Daskam, E., Jr., General Tel. Service Corp., New York, N. Y.
Dawson, E. J., Commonwealth Edison Co., Chicago, Ill.
Dean, L. A., Public Works Dept., 12th Naval Dist., San Francisco, Calif.
Dodson, W. B., American Air Filter Co., Louisville, Ky.
Foster, E. A., Fairbanks, Morse & Co., Chicago, Ill.
Friz, N., Esso Standard Oil Co., New York, N. Y.
Gray, H. H., Jr., Westinghouse Elec. Corp., Nashville, Tenn.
Green, C. F., General Elec. Co., Schenectady, N. Y.
Greim, C. C., Toledo Edison Co., Defiance, Ohio
Hanson, D. H. (re-election), General Elec. Co., Schenectady, N. Y.
Kearns, E. E., General Elec. Co., Erie, Pa.
Kearns, T., North Western Electricity Board, Fleetwood, Lancashire, England
Knapp, L. H., Blackstone Valley Gas & Elec. Co., Pawtucket, R. I.
Koellein, C. L., Jr., Nashville Bridge Co., Nashville, Tenn.
Lang, R. R., General Elec. Co., Schenectady, N. Y.
Lloyd, R. E., Hilburg-Byler & Hengstler, Los Angeles, Calif.
Mann, A. K., Office, Chief of Engrs., Washington, D. C.
Mayer, R., Minneapolis-Honeywell Regulator Co., Philadelphia, Pa.
McCrory, A. F., Hoosier Engg. Co., Columbus, Ohio
Mead, G. G., Jr., General Elec. Co., New York, N. Y.
Merchant, E. F., Stone & Webster Engg. Corp., Boston, Mass.
Narayanamurthy, P. V. A., (Gov't. Electricity Dept., Madras, India), c/o Westinghouse Elec. Corp., Pittsburgh, Pa.
Pate, R. C., Southern Bell Tel. & Tel. Co., Charlotte, N. C.
Pillai, P. R., (Madras Gov't. Electricity Dept., Madras, India), c/o Westinghouse Elec. International Co., New York, N. Y.
Pillsbury, A. H., Utilities Dept., City of Jacksonville, Fla.
Richardi, J. A., Marine Electronics, Inc., Baltimore, Md.
Rowe, G. C. B., Amer. Inst. of Elec. Engrs., New York, N. Y.
Ryder, E. A., Southern Bell Tel. & Tel. Co., Atlanta, Ga.
Spreadbury, F. G., Rotax Ltd., London, England
Twomey, C. F., Commonwealth Edison Co., Chicago, Ill.
Walz, R. F., Walkirt Co., Culver City, Calif.

42 to grade of Member

OF CURRENT INTEREST

Grand Coulee Dam, World's Largest Concrete Structure, Dedicated

Grand Coulee Dam on the Columbia River in the State of Washington, was dedicated recently by President Harry S. Truman. The construction of the dam was completed in 1941 and it is the largest concrete structure on earth, containing more than ten million cubic yards of concrete and weighing 22 million tons. It is the key structure for the Columbia Basin Project of the Bureau of Reclamation, which will provide irrigation water for an ultimate total of 1,029,000 acres of dry land in the Big Bend area in the eastern part of the state.

The dam serves the greatest power plant on earth, consisting of two powerhouses on the downstream toe of the dam. The 13 major generators now in operation can carry a peak load of 1,690,000 kw (2,264,000 horsepower) and could provide enough electricity to illuminate 3,400,000 average-sized homes. The ultimate installed capacity will be 1,974,000 kw.

Franklin D. Roosevelt Lake, which was also dedicated by President Truman, is the reservoir formed by Grand Coulee Dam and extends 151 miles to the Canadian Border. The lake began forming behind the dam in 1938 and first reached its maximum elevation of 1,288 feet above sea level in June of 1942.

Lake Roosevelt terminates in a waterfall at Grand Coulee Dam, where the water plunges 350 feet down the face of the dam to the river below. The fall is more than twice the height of Niagara, five city blocks wide, and covers an expanse of 15 acres. The billows of spray at the bottom of the fall sometimes reach a height of more than 100 feet.

The Grand Coulee Dam, although the largest in the world, is neither the highest nor the longest. Hoover Dam on the Colorado River is the highest (726 feet compared to 550 feet for Grand Coulee) and Fort Peck Dam on the Missouri River is the longest (four miles compared to 4,173 feet for Grand Coulee).

RCA Announces New 500-Kw "Super-Power Beam Triode"

A high-vacuum "super-power beam triode" capable of 500 kw of continuous output and tested at 1,000,000 watts input has been announced by the Radio Corporation of America's tube department.

The result of years of development by RCA engineers, the new tube, RCA type *5831*, represents the first commercial attempt to build power output of this magnitude into a single tube. Despite its enormous power input capabilities, the new tube is of compact design, measuring only $38^{3}/_{4}$ inches in length and weighing only 135 pounds.

Immediate applications of the new tube are in high-power continuous-wave applications and international service. In addition, the tube is expected to open the way to new developments in the high-power field which were hitherto economically unfeasible or impractical because of the banks of tubes and size of associated equipment required.

In unmodulated class *C* service, the *5831* has a maximum plate-voltage rating of 16,000 volts, a maximum plate input of 650 kw, and a maximum plate dissipation of 150 kw.

The new tube generates its tremendous power at high efficiency and with low driving power. To provide 500-kw output in unmodulated class *C* service, under typical operating conditions, the *5831* requires only about 900 watts grid drive. The tube can be operated with maximum rated plate voltage and plate input at frequencies throughout the standard broadcast band and much higher. Limitations for operation of the tube at high frequencies have not yet been determined.

Radically new design features have been

Future Meetings of Other Societies

American Chemical Society. Chicago Section—Sixth National Chemical Exposition. September 5–9, 1950, Chicago Coliseum, Chicago, Ill.

American Electroplaters' Society. Fourth International Electrodeposition Conference. June 12–16, 1950, Statler Hotel, Boston, Mass.

American Society for Engineering Education. Annual Convention. June 19–20, 1950, University of Washington, Seattle, Wash.

American Society for Quality Control. Fourth National Convention. June 1–2, 1950, Milwaukee, Wis.

American Society of Refrigerating Engineers. 37th Spring Meeting. June 4–7, 1950, Hotel Muehlebach, Kansas City, Mo.

American Society for Testing Materials. 53d Annual Meeting and 9th Exhibit of Testing Apparatus and Equipment. June 26–30, 1950, Atlantic City, N. J.

Edison Electric Institute. Annual Convention. June 5–7, 1950, Atlantic City, N. J.

Illuminating Engineering Society. National Technical Conference. August 21–25, 1950, Hotel Huntington, Pasadena, Calif.

Institute of the Aeronautical Sciences. Annual Summer Meeting. July 12–14, 1950, IAS Western Headquarters Building, Los Angeles, Calif.

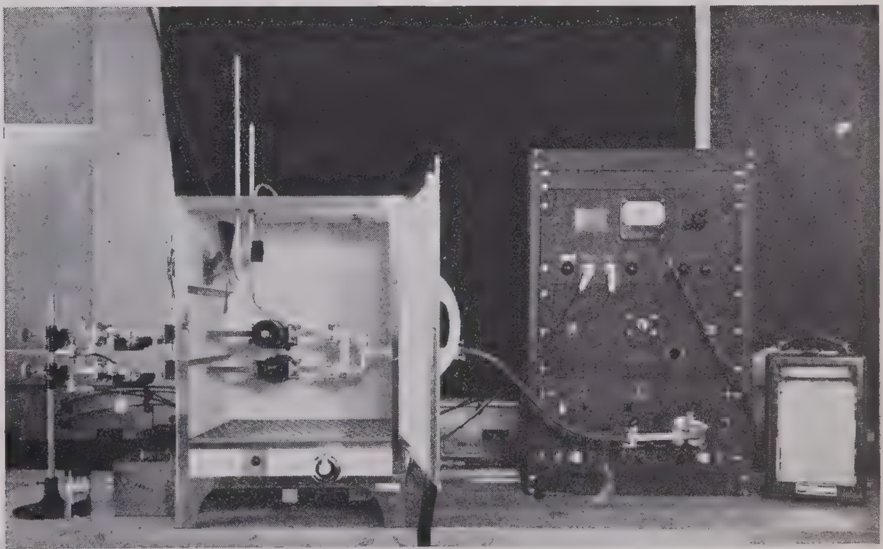
Instrument Society of America. 1950 Instrument Conference and Exhibit. September 18–22, 1950, Memorial Auditorium, Buffalo, N. Y.

International Conference on Large Electric High-Tension Systems (CIGRE). 13th Session. June 29–July 8, 1950, Paris, France.

National Association of Electrical Distributors. 42d Annual Convention. June 12–16, 1950, Convention Hall, Atlantic City, N. J.

National Society of Professional Engineers. Annual Meeting. June 8–10, 1950, Statler Hotel, Boston, Mass.

Recording Microwave Refractometer



This is a recording microwave refractometer developed by the National Bureau of Standards, Washington, D. C. It is used to measure the refractive index of an artificially controlled atmosphere. A klystron oscillator with its associated saw-tooth generator occupies the lower panel of the cabinet at the right. The klystron output, frequency-modulated with a saw-tooth wave, is fed through a flexible wave guide to a T-junction inside the temperature-controlled cabinet (center). The T-junction divides the signal between two cavity resonators, test and reference, respectively. The cavity outputs are passed through crystal detectors (left) and then back through coaxial lines to identical amplifier and pulse sharpener circuits (top panel at right). The combined output is graphed by the recording meter (far right)

incorporated into the *5831*, resulting in a structure unique in electron-tube design. The outstanding feature of the *5831* is an array of 48 independent unit electron-optical systems arranged cylindrically in the tube. The great power capabilities of this new tube are due largely to the successful achievement of this design, which, in effect, concentrates 48 triodes in relatively small space.

Corning Glass Develops New Electrically Conducting Glass

The Corning Glass Works, Corning, N. Y., has developed a new type of glass called E-C (electrically conducting) glass. While the principle of an electrically conducting glass is not new with the Corning Company, recent experimental work has produced new materials with improved properties greatly broadening the field of use.

One of the applications of the new glass is in the E-C radiant heater which has a transparent skin that conducts electricity, but resists enough to heat the glass up to 660 degrees Fahrenheit. The skin is a metallic oxide about 16-millionths of an inch thick. Currently, these heaters are being used to keep baby chickens warm in brooders, to dry textile yarn and the lacquer on plastic playing cards, as well as regular paper coating. A coffee percolator of E-C glass is also being developed which will start water perking to make coffee within 50 seconds. The coffee maker sets on a plastic base and two electrodes carry the current to the E-C skin coating the bottom of the coffee maker.

The glass can produce a wide range of temperatures depending upon the resistance of the film and the amount of current used. In industrial applications, E-C panels save space and give uniform heat.

The glass used is of the strong, tough, heat-resistant type. The electric skin is applied to the glass at a high temperature and is more resistant to scratching or to chemicals than the glass itself.

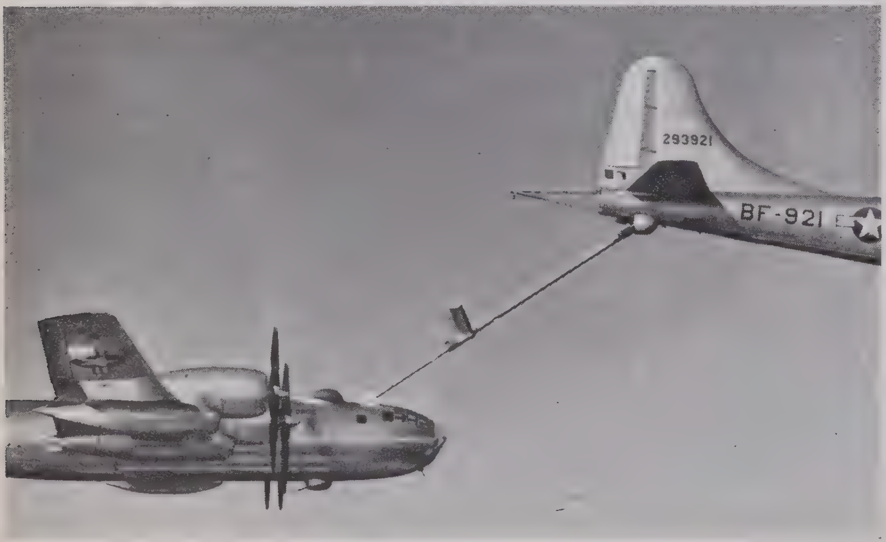
Young Industrial Executives Awarded Sloan Fellowships

Fourteen young industrial executives, winners in a nation-wide competition, have been awarded Alfred P. Sloan Fellowships for executive development at the Massachusetts Institute of Technology, Cambridge, Mass. The fellowships provide an intensive one-year program of study in management policies and economic and social problems of industrial administration.

These men, who have been nominated by their employers as showing unusual promise for industrial leadership, will receive fellowships up to $3,700. They will be on leave from their companies and upon completion of the program will return to the same companies.

The successful candidates are: Federico G. Baptista, chief petroleum engineer, Creole Petroleum Corporation, Caracas, Venezuela; John W. Bard, technical supervisor, Mill Technical Department, Marathon Corporation, Rothschild, Wis.; Carl A. Blanchard, Jr., assistant director of engineering, H. P. Hood and Sons Company, Boston, Mass.; William F. Brown, general foreman, Lubricating Oil Division, Continental Oil Company, Ponca City, Okla.; Edward P. Gruca, section leader, Research Division, Pullman-Standard Car Manufacturing Company, Hammond, Ind.; William W. Heilman, assistant to superintendent, Special Alloys, Electro-Metallurgical Division, Union Carbide and Carbon Corporation, Alloy, W. Va.; M. Robert Herman, Jr., assistant smelter superintendent, American Smelting and Refining Company, Barber, N. J.; Martin W. Kraegel, works engineer, American Steel Foundries, Hammond, Ind.; Robert H. Lucas, power engineer, Michigan Limestone and Chemical Company, Rogers City, Mich.; Dean E. Cogswell, assistant manager, Underwriting Department, New England Mutual Life Insurance Company, Boston, Mass.; Samuel K. McCauley, Wax Area foreman, The Atlantic Refining Company, Philadelphia, Pa.; George J. Todd, assistant to the manager, Underwater Ordnance Department, Pasadena Annex—Naval Ordnance Test Station, Pasadena, Calif.; F. Munro Veazie, in charge of Laboratory Cost Projection Department, Owens-Corning Fiberglas Corporation, Newark, Ohio; William M. Wallace, special assistant to manager, Basic Industries Machinery Department, Allis-Chalmers Manufacturing Company, Milwaukee, Wis.

Flying Boom in-Flight Refueling System



A new Flying Boom in-Flight refueling system developed by the Boeing Airplane Company Seattle, Wash., is shown in operation. In using the new refueling method the two airplanes fly in formation and the refueling boom, carried under the tail of the tanker airplane, is inserted into the special socket in the nose of the airplane being refueled. Fuel is delivered under pressure. Control of the fueling tube is made possible through the use of small V-shaped control surfaces known as "ruddevators," which govern movement of the fueling boom. A crew man in the rear turret of the tanker airplane operates the "ruddevator" controls and directs the fueling tube nozzle into the socket on the receiving airplane

CCNY Announces Courses in Salesmanship for Engineers

A new training program designed to relieve the extreme shortage of sales engineers will start June 19 at The City College of New York School of Business. Developed in close collaboration with an advisory board of nine industrial leaders, the Salesmanship for Engineers program will total 300 hours and will be completed in 15 weeks of daytime or 25 weeks of evening training.

The program will be open only to men with a technical background. They will be given no further engineering instruction but will get practical training in selling skills and marketing procedure. Classes will be conducted by sales training specialists who are conversant with engineering.

One-half of the course will be devoted to techniques of salesmanship, including such selling skills as the approach, the demonstration, meeting objections, and handling the interview. The largest portion of the remainder, 60 hours, is given over to practicing speech in selling. Thirty hours will be spent in a survey of industrial marketing, while the last 60 hours are evenly divided among market analysis, advertising, and marketing problem.

Further information about the new course may be obtained by writing to the Supervisor of Admissions, City College Midtown Business Center, 430 West 50th Street, New York 19, N. Y.

Bell Labs Develop Means for Computers to Correct Mistakes

A means for endowing modern computers with a whole new faculty—the ability not only to detect their own mistakes but actually to correct them—has been developed at Bell Telephone Laboratories, New York, N. Y.

The best that present computers can do is to recognize when they have made a mistake, and not all computers can do even this. Errors usually occur when a vacuum tube burns out or a switch fails to open or close properly. When this happens, some of the modern calculators will retrace their steps to the last check point and try again. If the same mistake recurs, they will stop and flash a light, ring a bell, or otherwise summon a repairman.

The laboratory model already constructed is designed to catch and correct one mistake and to catch—but not correct—two simultaneous mistakes. In the unlikely event that two simultaneous mistakes should occur the apparatus will so indicate and will summon help.

The method devised uses a combination of several odd–even checks to identify precisely the position of the error and thus allow it to be corrected. These checks are applied in a definite order at the sending end, and applied again at the receiving end in the same order.

Radar-like Pictures Show Heart and Brain in Action

Radar-like pictures of the heart and brain in action, made by equipment first developed at the Massachusetts Institute of Technology and now being extended at Syracuse University, may be a valuable new aid to medical science, according to a recent announcement.

The equipment in question picks up tiny electric impulses which flow through nerves in the body, as a telegraph impulse flows through a wire. These impulses are then converted into a constantly moving map-like picture similar to those made by World War II radar sets. The minute signals can be detected by electrical "pickups" on the surface of the body, basically nothing more than a small wire held against the skin with adhesive tape. In the case of heart studies, pickups are located at regular intervals in a square pattern on the left chest. To get pictures of the brain, similar recording points are fastened to the skin of the scalp. The patient feels nothing.

Electronic "maps" of the brain have shown for the first time that in it there are actual waves of electric energy with specific paths and very definite speeds; some of these cover the entire brain, and some are confined to one of its various parts. Conventional techniques of measuring these so-called "brain waves" at a number of specific points by a process known as electroencephalography have been used for many years, but no visible picture of over-all brain activity has been available until now.

Hughes Awards for 1949 Presented to Six Companies

The national George A. Hughes awards for 1949 were presented recently to six electrical companies that conducted outstanding educational and promotional activities to advance electrical living last year. Offered each year by Hotpoint, Inc., Chicago, Ill., the awards are sponsored by the Edison Electric Institute. Prizes were presented to winners in five classifications of promotional activity; Class I, electric kitchen; Class II, domestic electric range; Class III, electric water heater; Class IV, electric dishwasher; and Class V, commercial electric cooking.

Class I winners were the Pennsylvania Power and Light Company, first prize, and the Gulf States Utilities Company, second prize. The West Penn Power Company and the Kentucky and West Virginia Power Company were first and second prize winners, respectively, for Class II. Class III prizes were won by the West Penn Power Company and The Detroit Edison Company. First prize winner in Class IV was the Pennsylvania Power and Light Company. In Class V, the Toledo (Ohio) Edison Company took first prize, while the second prize went to the Pennsylvania Power and Light Company.

New Standard and Recommended Practices. The American Standards Association has published a revised Standard, "Relays Associated With Electric Power Apparatus," which relates only to relays of types designed primarily for industrial control, excitation or governor regulating, telephone, telegraph, traffic signal, or similar purpose. The AIEE has published "Recommended Practice for Testing Insulation Resistance of Rotating Machinery," with recommendations applying to three types of integral kilowatt rotating apparatus; synchronous machines, induction machines, and d-c machines, including synchronous converters. Both of these publications are priced at 60 cents with 50 per cent off to AIEE members. A third publication, "Recommended Practice for Minimization of Interference From Radio-Frequency Heating Equipment," published by the AIEE, is available for 80 cents to nonmembers and 40 cents to members. This is not an AIEE Standard and the recommendations are not intended to be mandatory or restrictive. The publication reviews the theoretical aspects of the interference problem and then outlines procedures which should be followed.

RCA "Printed Circuit" Tuner Announced for Television

The television industry's first "printed-circuit" television tuner, which provides improved performance in home receivers, including better reception in fringe areas, has been announced by the Radio Corporation of America, Camden, N. J.

A radical departure from conventional wound-coil units, RCA's new "printed-circuit" tuner utilizes a photo-etch process to reproduce the critical circuits. The process eliminates the complicated process of mechanically winding separate coils, and at the same time produces precision circuits of superior performance.

In design, the new unit is a cylindrical turret-type tuner. The turret assembly employs individual coil strips or segments, each containing the printed circuit for a separate television channel. The strips are easily removed for service or replacement. All the tuned circuits are printed with the exception of the oscillator coils for channels two to six.

Tuning is accomplished by rotating the turret by means of a conventional channel-selector switch which connects with the proper coils for each channel.

Lehigh University Sets Up New Five-Year Program

Lehigh University, Bethlehem, Pa., has adopted a new 5-year curriculum in electrical engineering and engineering physics. In establishing the combined program of studies, the faculty educational policy committee reported that the project was adopted to fill a special need. The combined curriculum is not designed to attract the average student but those with particular interests in the communications fields.

In setting up the new program, the committee has established an equal number of required hours in electrical engineering, physics, mathematics, and the social sciences and humanities. A summer of industrial employment will be a requisite between the third and fourth years. Included among the required humanities and social science courses are economics, composition and literature, and development of Western civilization. General study or approved electives are provided during the last three years.

Students in this new program will be granted a Bachelor of Science degree in electrical engineering at the end of the fourth year, and the degree of Bachelor of Science in engineering physics at the end of the fifth year.

NY State Employment Service Placed 346,000 During 1949

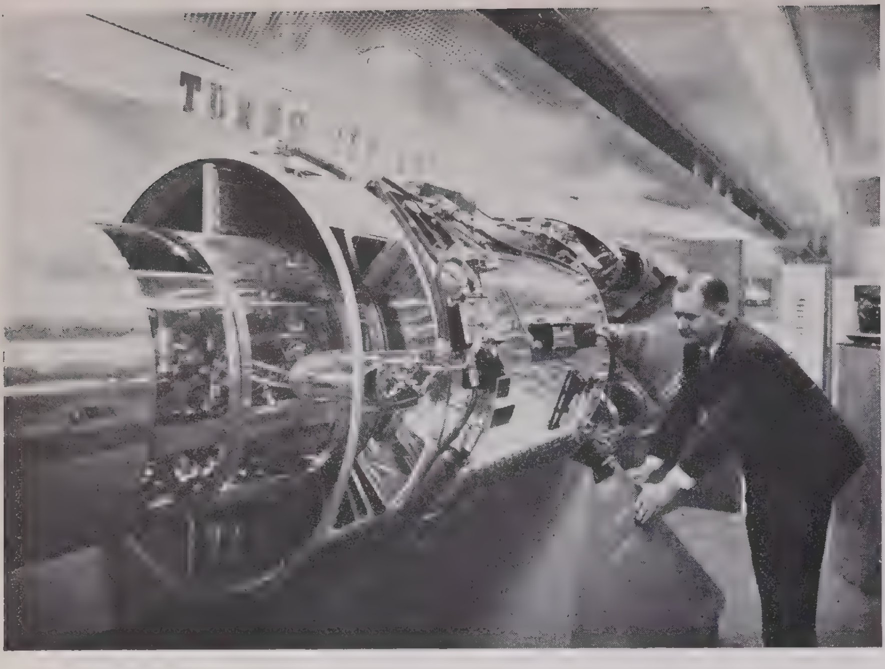
The United States Employment Service serves as a clearing house where qualified workers may register for work and employers may place their job openings. During 1949, the New York State Employment Service, an affiliate of the United States Employment Service, placed 346,000 persons in the state of New York.

In New York City, during 1949, more than 3,400 professional positions in salary ranges up to $10,000, approximately 400 of which were engineering positions, were filled by the non-fee-charging Clerical and Professional Office of the New York State Employment Service. In addition, over 26,000 office jobs with New York City firms were filled. During this same period, 222,000 jobs in New York City were filled by the ten highly specialized offices of the New York State Employment Service.

Applicants qualified in every respect to meet employers' requirements are carefully screened by thoroughly trained interviewers. The employer makes the final selection and he pays no fee nor does the applicant.

To interview selected candidates for professional, technical, or office positions, contact the local branch of the United States Employment Service.

Nonferromagnetic Synchrotron. Successful operation in its first phase of a new type of atom smasher, which is ultimately expected to produce X rays of 300,000,000 volts, has been announced by the General Electric



This is a full-size cutaway model of the J-47 turbojet engine, one of several displays in the National Security section of the More Power to America Special which is being launched on a nation-wide tour by the Apparatus Department of the General Electric Company, Schenectady, N. Y. The J-47 type engine powers the North American F-86, Air Force fighter airplane which in 1948 set the world's speed record of more than 670 miles per hour. It is also used in several other military aircraft

Company, Schenectady, N. Y. The new machine is known as a nonferromagnetic synchrotron and is being built under the joint sponsorship of the Office of Naval Research and the G-E research Laboratory. It has been operated thus far up to about a million volts and will probably be in operation at much higher energies before the end of the year. It will be used to study the effects of high-energy radiation, particularly in nuclear research. The new particle accelerator, or atom smasher, is of a design that eliminates the huge iron-core electromagnet commonly used in such devices. The requisite powerful magnetic fields are produced solely by specially designed coils of wire. These carry heavy currents, and are contained in a steel tank from which air has been exhausted.

Engineers in the Banking Business. At the recent Spring Meeting of the American Society of Civil Engineers, A. J. Gock, Chairman of the Board of the Bank of America, told the members of the society that bankers need the special talents and training of engineers in the banking business. Mr. Gock said that with increasing frequency bankers are encountering scientific and technological problems, which few bankers have the necessary background and experience to interpret successfully. Engineers, on the other hand, have had a specialized type of training which involves the solution of problems. The engineer's training is of the type that produces an analytical mind. He is interested in trends and relationships. It is for these reasons, Mr. Gock believes, that a potential market exists for the services of engineers, not alone among bankers, but among businessmen in general.

Increased Definition in Theater Television. Projection of theater-size television images of higher definition than those available from any present program source will be possible with a new theater television projector, Model *PT-100*, developed by the Radio Corporation of America, Camden, N. J. The video amplifier of the *PT-100* has been designed to pass the full 8-megacycle band generally agreed upon by television engineers as the optimum channel required for a high-definition theater television service. The Schmidt-type projection optical system of the projector is capable of resolving a 1,000-line image. Although the equipments now in production are set to operate with the 525-line broadcast programs now available to theaters, they can be readily adapted to make use of a substantially greater number of scanning lines which might be employed in future closed-circuit programming for theaters.

New AEC Geiger Counter. An inexpensive Geiger counter designed to measure high levels of radiation has been developed by the instrument laboratory of the New York Operations Office of the United States Atomic Energy Commission. Upon completion of industrial engineering, the Commission expects to submit the new instrument to the National Security Resources Board for consideration as a radiation detection device suitable for civilian defense purposes. In its present form, the instrument is not designed for prospecting or other low-level monitoring, and cannot be used for these purposes without modification. Therefore, whether or not this high-level detection instrument is manufactured may depend upon civil defense requirements for monitoring devices.

Breaking Gallstones by Sound Waves. A new technique for breaking gallstones by high-frequency sound waves was reported recently by three doctors at the annual meeting of the American Physiological Society in Atlantic City, N. J. The experiments have been restricted to anesthetized rabbits and a dog and open up the possibility that gallstones may be treated some day without surgery. If gallstones can be successfully fragmented by high-frequecy sound waves, or ultrasound, the small, broken pieces may then pass into the intestines and be excreted through natural elimination. Thus far, the doctors have limited their research to the proof of two basic points: first, that gallstones can be fragmented by ultrasound; and second, that live animal tissue surrounding the gallstones need not be damaged during the brief exposure to ultrasound.

G-E's Electrical Display Train. The General Electric Company, Schenectady, N. Y., recently unveiled its "More Power to America Special," a 10-car exhibit train displaying in one series of related exhibits the complete range of products for the production, distribution, and industrial utilization of electric power. The train will visit approximately 150 key industrial centers throughout the United States during 1950 and 1951. At each stop the train will be inspected by invited representatives of electrical utilities, the manufacturing and transportation industries, the armed services, the Federal government, and municipalities. The train will not be open to the general public during its tour as the exhibits aboard the train have been designed specifically to interest those who produce electric power and those who put it to work in industry and the community.

ASTE Sets Up Research Foundation. Setting up of a research foundation to carry on basic production research was authorized recently by the Board of Directors of the American Society of Tool Engineers. An initial fund of $25,000 was appropriated at the same time. Plans call for the use of existing production research facilities at various universities and colleges. The foundation also will act as an intermediary to assist small industries or companies interested in basic research but not in a position to finance such research. The ASTE Board of Directors also adopted a resolution to work with the Army Ordnance Association on national preparedness plans. A $25,000 scholarship fund offered by an anonymous Chicago concern to permit increased tool engineering scholarships in the state of Illinois was accepted by the Board.

Ionospheric Physics Conference. A conference and symposium designed to acquaint scientists in the field of physics, relative to the upper atmosphere, with the latest theoretical and experimental developments, will be held at The Pennsylvania State College, July 24–26, 1950. Approximately 12 papers will be presented by some of the foremost scientists in this field today. Speakers from several foreign countries are expected to participate in the presentations. Several symposia are planned to allow free intermingling of the latest ideas among the participants. The conference is being sponsored jointly by The Pennsylvania State College and the Geophysical Research Directorate of the United States Air Force. Further details may be obtained from Dr. A. H. Waynick, Radio Propagation Laboratory, The Pennsylvania State College, State College, Pa.

Industrial Research Conference. The Department of Industrial Engineering of Columbia University, New York, N. Y., announced recently that it will conduct a 5-day conference on the Costs, Budgeting, and Economics of Industrial Research from June 12 through June 16, 1950. Experts from industry and the university will participate in lectures, discussions, and clinic sessions designed for the practical research and development administrator. Additional information may be obtained by writing Professor David Bendel Hertz, Department of Industrial Engineering, 409 Engineering, Columbia University, New York 27, N. Y.

Multichannel Recorder for Aviation Safety. A new multichannel magnetic tape recorder designed and manufactured by The Brush Development Company, Cleveland, Ohio, has been installed at Los Angeles, Seattle, and San Francisco airports. The unit, capable of recording 14 channels simultaneously, makes possible for the first time in aviation history an exact record of all reports and communications between both pilots and control tower operators. The recorder will fill a basic need for the elimination of contradictions and confusion in determining exact conversation in investigation of accidents to airplanes during take-off, approach, and other operational phases.

Atomic Power Not for Automobiles. In a recent talk, Dr. Lewi Tonks of the General Electric Company, Schenectady, N. Y., said that nuclear power will never be used for what he calls "small tasks." Dr. Tonks gave three reasons for his statement: first, an atomic power plant will not run unless it contains a certain amount of fuel, and with this minimum, it is not economical to run unless tens of thousands of kilowatts are generated; second, skill in handling and maintaining delicate controls would be beyond the ability of the average driver; and third, to protect persons in the vicinity of an atomic power plant, huge shields weighing hundreds of tons are needed.

Design Awards Competition. The Gage Publishing Company, New York, N. Y., announces the 12th Annual Electrical Manufacturing Product Design Awards Competition, five cash awards totaling $2,500 being offered for case-history stories that depict the greatest accomplishments in product design and development. The competition is sponsored by the publishers to stimulate and encourage those engaged in the design and engineering of electrically operated products and to accord appropriate recognition for outstanding achievement. Certificates of Award will be presented to successful contestants, also to five companies designated by the Jury of Award for honorable mention. Entries are now being accepted and the closing date for filing of manuscripts is June 30, 1950. Award-winning stories will be published in the Twelfth Annual October Product Design Awards Number of *Electrical Manufacturing*.

Approved ASA Standards Increasing. A report and chart issued by the American Standards Association show that the number of new and revised American Standards approved during 1949 was almost twice the average number approved annually during speeded-up activity of five war years. The 268 approvals last year bring the total number of American Standards to 1,121 and total revisions to 1,014. The latter number indicates the importance attached to keeping Standards up to date, as necessitated by new developments in materials and methods, new experience, and improvements or changes in conditions.

National Fire Loss. At a recent meeting of The National Fire Waste Council in Washington, D. C., it was pointed out that the national fire loss in 1949 amounted to 700 million dollars. This is equivalent to a $5 per capita loss. The Council is attempting to reduce this loss which is enormous, particularly when it is compared with the figures for Great Britain, where the loss is 50 cents per capita, and in Germany, where the loss is 12 cents per capita. The majority of fires are due to carelessness and the next most common cause is defective wiring. The major steps in any locality to reduce the fire loss should be the adoption and enforcement of a fire prevention code.

Radar Pioneer Honored. Lawrence Hyland, Vice-President of the Bendix Aviation Corporation, Detroit, Mich., was presented with the United States Navy's Distinguished Public Service Award recently for discovering that rebounding radio waves could show the presence and location of an airplane in the sky. Mr. Hyland made his discovery in 1931 at the Anacostia Naval Air Station, while transmitting radio signals from the ground to an airplane in flight in connection with high-frequency direction-finding research.

Electronic Engineering Index. The 1949 edition of The Electronic Engineering Master Index published by the Electronics Research Publishing Company, New York, N. Y., will be available in June. The 1949 edition, the fourth volume in the series that starts with the 1925–1945 issue, completely indexes 8,500 articles from nearly 400 world-wide scientific periodicals, journals, proceedings, and technical house organs for the year 1949. Also listed are the 4,000 applicable patents granted by the United States Patent Office during 1949.

NBS Develops Omegatron. The omegatron, a recent development at the National Bureau of Standards in the realm of atomic instrumentation, is basically a miniature cyclotron which makes possible measurement of the numerical value of the faraday with high precision. For the first time the faraday is being evaluated directly by physical methods. All previous faraday measurements have been electrochemical. The value of the nuclear magnetron may now be determined very precisely, so that the ratio of the mass of the electron to the mass of the proton will be known with greater precision than ever before. The omegatron operates on the same fundamental principle as a large cyclotron, yet the heart of the instrument is little larger than a package of cigarettes.

B. H. Allen Joins Personnel Service. The Engineering Societies Personnel Service, Inc., has announced the appointment of Bonnell H. Allen as assistant to Joseph R. Decker, manager of the Chicago, Ill., office of the service. Mr. Allen is a licensed engineer with a background of a number of years of engineering personnel placement work.

Bonneville to Install Philco Microwave. The Philco Corporation has been awarded a contract to supply the Bonneville Power Administration of the United States Department of the Interior with microwave communications relay equipment and associated multiplex and telephone terminating equipment to provide 700 miles of communications channels plus spur links. This microwave relay system will operate at frequencies in the vicinity of 7,000 megacycles per second, using parabolic antenna-reflectors supported on towers located from 15 to 30 miles apart and at Bonneville's principal substations, stations, and power plants of the Federal generating system.

Sylvania's New Nickelclad Copper Wire. Heat-resistant nickelclad copper wires which provide the good electrical conductivity of copper combined with the heat and corrosion resistant properties of nickel have been announced by the Parts Division, Sylvania Electric Products, Inc., Warren, Pa. Sylvania is specializing in diameters ranging from 0.010 inch to 0.005 inch which are well suited for stranding and for lead wire applications where high-temperature working of hard glass frequently renders solid copper wires brittle and unworkable, as in the processing of high-wattage incandescent lamps and electron tubes.

Regulators Reduce X-Ray Plate Spoilage. Application of automatic induction voltage regulators by the General Electric Company, Schenectady, N. Y., has reduced the rejection of X-ray plates at the X-Ray Laboratory of St. Lukes Hospital, Chicago, Ill. When the hospital changed from d-c to a-c power, the laboratory was confronted with fluctuating voltage conditions and interruptions, since the same power source also supplied power to several other parts of the hospital. After installing the General Electric regulators, rejections dropped from as high as 50 per cent rejections to practically no rejections due to power fluctuations.

1950 Summer Electronics Symposium. As a part of the 1950 summer session of the University of Michigan, the department of electrical engineering will offer an 8-week specialized Summer Electronics Symposium, presenting visiting lecturers from other universities and from various industrial and governmental laboratories. The Electronics Symposium will run from June 26 to August 18. A special bulletin giving details is available from the Office of the Summer Session, Administration Building, University of Michigan, Ann Arbor, Mich.

Webster Chairman of RDB. William Webster, Executive Vice-President, New England Electric System, Boston, Mass., was recently made Chairman of the Research and Development Board, Department of Defense, Washington, D. C. From 1948 to 1949 Mr. Webster was Chairman of the Board's Committee on Atomic Energy, deputy to the Secretary of Defense on Atomic Energy Matters, and Chairman of the Military Liaison Committee to the Atomic Energy Commission. Since 1949 he has been a consultant to the Office of the Secretary of Defense and the Atomic Energy Commission.

Aircraft Fire-Warning Instruments. Fire-warning instruments operating on the principle of detecting and measuring carbon monoxide in atmosphere of baggage compartments and hydraulics hatches have been installed in 46 *Canadair Four* commercial transport airplanes now in the regular service of two Canadian and one British air lines. An accepted fire-detecting and locating method in the mining industry, the carbon monoxide measuring principle was adapted for aircraft by the Mine Safety Appliances Company, Pittsburgh, Pa.

Westinghouse Gets Egyptian Power Order. A $5,337,000 order for a 45,000-kw steam-electric generating station to aid drainage and irrigation work along the Nile has been placed with the Westinghouse Electric International Company by Egypt's Ministry of Public Works. The new power station, to be located at Talkha, about 90 miles north of Cairo on the east branch of the Nile, will be the largest plant tying into the electrical network which supplies power to pumping stations in the delta region.

G-E Ships Large Mine-Hoist Motor. The largest mine-hoist motor in the United States from the standpoint of physical size has been shipped by General Electric's Large Motor and Generator Divisions to the Anaconda Copper Mining Company, Butte, Mont. The 600-volt d-c motor, rated 3,000 horsepower at 60 rpm, will drive an ore hoist at the Kelley Shaft, an important part of Anaconda's $20,000,000 "Greater Butte Project" for the recovery of low-grade copper ore by the caving method. When installed, the motor will be direct-connected to the hoist drums.

Marvel-Schebler Carburetor Relocates. All manufacturing and administrative activities of the Marvel-Schebler Carburetor Division of the Borg-Warner Corporation, now located in Flint, Mich., will be transferred to Decatur, Ill., in the late summer or early fall of this year. The Marvel-Schebler operation, which is expected to provide employment for about 400 persons in Decatur, will be housed in a 135,000-square-foot plant which Borg-Warner leased from the Mueller Company in May 1948.

LETTERS TO THE EDITOR

INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, Electrical Engineering reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are expressly understood to be made by the writers. Publication here in no wise constitutes endorsement or recognition by the AIEE. All letters submitted for publication should be typewritten, double-spaced, not carbon copies. Any illustrations should be submitted in duplicate, one copy an inked drawing without lettering, the other lettered. Captions should be supplied for all illustrations.

Why Go the Way of Britain?

To the Editor:

In the April issue of *Electrical Engineering* the article entitled "Why Go the Way of Britain" (*EE, Apr '50, pp 293–5*) has aroused my interest and brought to mind several questions on editorial policy.

May I first express my approval and complete satisfaction of *Electrical Engineering's* selection and presentation of technical articles. These articles are always based on sound engineering principles and arranged in a logical and systematic form. The high degree of accuracy and thorough preparation makes each article indeed a pleasure and a vast wealth of informative reading. I have prepared several papers for our local AIEE Section, so therefore realize the extent of preparation required.

I am quite perplexed at the magazine's selection of the afore-mentioned article. This perplexity is due primarily to the lack of factual information on which all sound logic must be based. Secondly, it is due to its lack of definition of terms, and, thirdly, to its attack on our form of government.

Sir Ernest Benn stated, "socialism is not a system, it is a disease...." Do you believe that this definition is accurate, sound, or logical? Should not the same principle of accurate facts be applied to the presentation of articles dealing with social sciences as applied to electrical sciences? I am sure that *Electrical Engineering* would not publish any technical article that based its premise of reasoning or fact on the definition of an ampere as a unit of resistance. Sir Benn discusses individualism versus collectivism on the basis that individualism makes a man stand on his own merits yet has not this magazine strongly endorsed collectivism in the form of registration of all electrical engineers and furthermore endorsed the assignment of each engineer a number for the collective good of the majority? Sir Benn no doubt practices collectivism to some extent himself in his own organization.

In closing the author forthright implies the overthrow of our form of government. It is crystal clear that Sir Benn has overlooked the basic fact that our government's policies are the will of the majority of the people. It is likewise quite obvious the British Government has chosen socialistic changes at the will of the majority of the people of Britain. What minority group does Sir Benn represent?

In closing, I would like to answer the question with which Sir Benn entitled his article. That answer is, we shall go the way of Britain towards socialism to the degree that best fits the needs of the majority of the people of the United States of America.

GEORGE S. GAUDEN, JR. (A '43)
(North Hollywood, Calif.)

To the Editor:

It was indeed gratifying to find in the April issue of *Electrical Engineering* the inspiring and informative article "Why Go the Way of Britain?" by Sir Ernest Benn. In words whose clarity is exceeded only by their basis in fact he has pointed out that the fundamental ill in our present social and economic trends is our loss of the concepts of morality and natural law.

JOHN A. HALVORSON (A '47)
(Cutler-Hammer, Inc., Milwaukee, Wis.)

To the Editor:

I was very much interested in the article "Why Go the Way of Britain?" by Sir Ernest Benn in the April issue of *Electrical Engineering*.

We are fast approaching this "way" so to speak and I feel that every businessman in the United States should be acquainted with this issue regardless of his political affiliation.

A. A. ABRAHAMS (A '47)
(Federal Oil Burner Company, Inc., Philadelphia, Pa.)

Constants of 2-Speed Consequent-Pole Induction Motors

To the Editor:

Designers, students, and others frequently are confronted with questions concerning the number of conductors, leakage and magnetizing reactances, resistances, winding pitches, and connections needed to obtain variable torque, constant torque, or constant horsepower at the two speeds. No precise information is available. Only the connections needed are given in Bulletin *C 6*—1938 of the American Standards Association.

The speed change is accomplished by changing the polarity of one-half of the stator winding so that the poles are changed from, say, *NSNS* to *NNSS*. This results electrically in the conditions enumerated in the following.

Variable Torque. Changing connections from 1-Y to 2-Y changes the speed from low to high. If 100 conductors are in series per phase on low speed, then on high speed this figure is 50. Since half of these cancel out, only 25 will be active. The flux per pole will nearly quadruple and the gap flux density will nearly double. The departures are due to the difference in distribution factors.

Constant Torque. Changing from 1-Δ to 2-Y changes the speed from low to high. As before, of 100 conductors in series per phase on low speed, 25 will be active on high speed. If the volts per phase are 220 on low speed, they will be $220/\sqrt{3}$ on high speed. The flux per pole goes up nearly in the ratio $4/\sqrt{3}$, and the gap flux density nearly in the ratio $2/\sqrt{3}$.

Constant Horsepower. Changing from 2-Y to 1-Δ changes the speed from low to high. The number of conductors in series will be the same on both speeds. On high speed half of these cancel out leaving 50 active. If the volts per phase are $220/\sqrt{3}$ on low speed and 220 on high speed, the flux per pole will go up nearly in the ratio $\sqrt{3}/1$ and the gap flux density nearly in the ratio $\sqrt{3}/2$. The reasons for the preceding statements will be clear when we observe that if the coils are full pitch for low speed then mechanically they will be half pitch for high speed. Two narrow adjacent coils act as one wide full-pitch coil. For high speed, the two layers in one-half of the slots carry currents in opposite directions. This has the following effects:

(*a*). The external magnetomotive forces of the "dead" slots and the zigzag fluxes in their vicinity disappear.

(*b*). The slot leakage fluxes in the dead slots are greatly reduced.

(*c*). The winding distribution factor increases as indicated in Table I.

Table I. Distribution Factors of 2-Speed Windings

Slots Per Pole on Low Speed	Active Slots Per Pole Per Phase (Both Speeds)	Distribution Factor: Full Pitch	Distribution Factor: Half Pitch
3	1	1.000	1.0000
6	2	0.966	0.9914
9	3	0.960	0.9899
12	4	0.958	0.9893
15	5	0.957	0.9891
18	6	0.956	0.9889
∞	∞	0.955	0.9886

Magnetizing Reactances. These are calculated in the regular way. It is necessary to remember that on high speed only half of the stator conductors actually in circuit are counted, with a higher distribution factor.

Primary Resistances. These are calculated in the regular way, keeping in mind the number of parallel branches per phase and the actual number of conductors in series.

Secondary Resistances. These too are calculated in the regular way. It is necessary to remember that on high speed only half of the number of stator conductors actually in circuit are counted, that the distribution factor goes up, and that the end-ring component of resistance goes up four times.

Leakage Reactances. On low speed, the winding for each torque case is equivalent to an ordinary full-pitch single-speed winding. Therefore, the corresponding leakage reactances can be figured by any standard method. The components on low speed may be represented by

Primary slot $= x_{s1}$
Secondary slot $= x_{s2}$
Primary zigzag $= x_{z1}$
Secondary zigzag $= x_{z2}$
Primary end $= x_{e1}$
Secondary end $= x_{e2}$
Differential = ( )
Skew = ( )

In line with the most common practice, the leakage reactance X in ohms per phase will be taken as the sum of the first six components.

On the high-speed connections, the slot and zigzag leakages for half of the slots disappear. When the stator winding has two parallel paths, as in the variable torque and constant torque cases, these components drop to $1/2 \times 1/4 = 1/8$ of the values they had on low speed with one path.

For constant horsepower with two paths on low speed and one path on high speed by similar reasoning the multiplier is $1/2 \times 4 = 2$. For the end connections, we assume that the permeance goes up four times when the number of poles is halved. This means then that for the first two torque cases the factor is $4/2 = 2$, and in the third case $2 \times 4 = 8$.

The so-called dead slots contribute a small additional component of stator slot reactance whose value is proportional to $X_{s1} \dfrac{K_-}{K_+}$, where

$K_- = \dfrac{b}{6s} + \dfrac{t}{4s}$ is the stator slot constant for the subtractive condition
K_+ is the standard stator slot constant for the additive condition
b = radial depth of copper in one stator coil side
s = stator slot width, assuming parallel sides
t = radial distance between copper in the two coil sides.

Only two terms are present in K_- because the magnetomotive force across the tooth tips is zero. The procedure for the high speeds is shown in Table II.

When applied to a certain 50-horsepower motor with 8 and 4 poles, using always a total of 240 stator conductors for each phase, the calculated pull-out torques in the foregoing order were

83.5 and 254 pound-feet
250.5 and 254 pound-feet
334 and 181 pound-feet

When the same maximum gap flux densities are used, allowing for the difference in distribution factor, these pull-out torques become

294 and 254 pound-feet
294 and 254 pound-feet
294 and 159 pound-feet

Coil pitches other than those considered are used also. For the low-speed connections, the effects of chording can be taken into account in the same way as for a single-speed winding. The conditions for the high-speed connections are beyond the scope of this letter.

Table II. Leakage Reactances for High-Speed Connections

Component	Variable Torque	Constant Torque	Constant Horsepower
Primary slot, additive	$0.125\, x_{s1}$	$0.125\, x_{s1}$	$2\, x_{s1}$
Primary slot, subtractive	$0.125\, x_{s1} \dfrac{K_-}{K_+}$	$0.125\, x_{s1} \dfrac{K_-}{K_+}$	$2\, x_{s1} \dfrac{K_-}{K_+}$
Secondary slot	$0.125\, x_{s2}$	$0.125\, x_{s2}$	$2\, x_{s2}$
Primary zigzag	$0.125\, x_{z1}$	$0.125\, x_{z1}$	$2\, x_{z1}$
Secondary zigzag	$0.125\, x_{z2}$	$0.125\, x_{z2}$	$2\, x_{z2}$
Primary end	$0.5\, x_{e1}$	$0.5\, x_{e1}$	$8\, x_{e1}$
Secondary end	$0.5\, x_{e2}$	$0.5\, x_{e2}$	$8\, x_{e2}$

The ohms per phase X then equal the sum for the appropriate column.

A. F. PUCHSTEIN (M '27)

(The Jeffrey Manufacturing Company, Columbus, Ohio)

NEW BOOKS • • • • •

The following new books are among those recently received at the Engineering Societies Library. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books in question.

GEWÖHNLICHE DIFFERENTIALGLEICHUNGEN. By G. Poppovic. Franz Deuticke, Vienna, Austria, 1950. 56 pages, diagrams, $8^1/_4$ by $5^1/_2$ inches, paper, 3 D.M. This pamphlet serves as an introduction to the subject of differential equations and presents methods for their solution. A background knowledge of differential and integral calculus is assumed. Examples are included from the fields of electrical and mechanical engineering.

WELDING HANDBOOK. American Welding Society, compiler and publisher, 33 West 39th Street, New York 18, N. Y. Third edition, 1950. 1,651 pages, illustrations, diagrams, charts, tables, $9^1/_4$ by 6 inches, cloth, $12 in United States and Canada, $13 elsewhere. This standard handbook contains 65 chapters covering the more than 30 welding and cutting processes used by industry today, the welding of ferrous and nonferrous metals and alloys, and the application of welding in different industries. Also included are individual chapters on cost estimating, welding metallurgy, physics of welding, a dictionary of welding terms, general engineering tables, welding symbols, and inspection methods.

DER ULTRASCHALL UND SEINE ANWENDUNG IN WISSENSCHAFT UND TECHNIK. By L. Bergmann. Fifth revised and enlarged edition. S. Hirzel Verlag, Zürich, Switzerland, 1949. 748 pages, illustrations, diagrams, charts, tables, 9 by 6 inches, linen, 60 Sw. Frs. This monograph is a comprehensive review of the current state of ultrasonic research. Completely revised to include the latest data on the subject, the major changes in Part I include new sections on the air-jet pulsator and the ultrasonic whistle, as well as on the determination and measurement of sonic fields. In Part II, sections on magnetostriction, on sound absorption in solid bodies, and on new uses of ultrasonics in communications and materials testing have been added.

LA TECNICA DEI RADIOTRASMETTITORI. By G. Bronzi. Nicola Zanichelli Editore, Bologna, Italy, 1949. 403 pages, diagrams, charts, tables, 10 by 7 inches, paper, lire 4,000. This text on radio transmitters covers theory, circuits, and equipment for both telecommunications and broadcasting. Section I covers the low-frequency field, and Section II, high-frequency. Sections III and IV cover amplitude, phase, and frequency modulation. A bibliography accompanies each section.

(A) SYMPOSIUM ON ELECTRONICS IN RESEARCH AND INDUSTRY, Papers read at the First Symposium on Electronics in Scientific Research and Industry, 1948. Published in collaboration with the Scientific Instrument Manufacturers Association of Great Britain Ltd. by Chapman and Hall, London, W.C.2, England, 1949. 199 pages, illustrations, diagrams, charts, tables, $8^3/_4$ by $5^1/_2$ inches, cloth, 16s. This symposium compiles the most recent developments in the application of electronic methods to the solution of all types of instrument problems. Computing, frequency measurements, measurement of small displacements, measurement of ionizing radiations, and other uses in research are discussed in the first half of the book. Applications to industrial problems are presented in the second half.

DIE SELBSTTÄTIGE REGELUNG, THEORETISCHE GRUNDLAGEN MIT PRAKTISCHEN BEISPIELEN. By A. Leonhard. Springer-Verlag, Berlin, Göttingen, and Heidelberg, Germany, 1949. 284 pages, diagrams, charts, tables, $9^1/_2$ by $6^1/_4$ inches, paper, 24 D.M.; bound, 27 D.M. Discusses the basic theoretical principles of automatic control as well as practical examples of its use. Following a chapter on fundamentals, the determination of a suitable control process is considered in detail. The stability of control is then inspected. The final chapter is devoted to methods for the determination of appropriate control constants.

SCHOLARSHIPS, FELLOWSHIPS AND LOANS. By S. N. Feingold. Bellman Publishing Company, 83 Newbury Street, Boston 16, Mass., 1949. 254 pages, $9^3/_4$ by $6^3/_4$ inches, cloth, $6. The information given in this new reference book is listed alphabetically by administering agency with address, name of grant, qualifications, funds available, special fields of interest and information, and where to apply for information. In an introductory section the author discusses career planning and aids. The latter part of the book contains a bibliography, a subject index, and indexes of the administering agencies and names of grants.

RADIO ENGINEERING, Volume 2. By E. K. Sandeman. Chapman and Hall, Ltd., London, W.C.2, England, 1949. 579 pages, diagrams, charts, tables, 9 by $5^{3}/_{4}$ inches, fabrikoid, 40s. Completing a 2-volume set, this book is designed to give beginners in radio the working principles they need. Experienced engineers and designers of radio circuits and equipment may also use it as a reference volume. This volume contains an extensive classified bibliography and a cumulative index to both volumes.

OUTLINE OF RADIO, TELEVISION and RADAR, a Symposium. Chemical Publishing Company, Brooklyn, N. Y., 1950. 688 pages, illustrations, diagrams, charts, tables, $8^{3}/_{4}$ by $5^{3}/_{4}$ inches, cloth, $12. Presents an elementary outline of the principles upon which the whole science of radio is based. It shows how the necessary components of a radio circuit are designed to fulfill the theoretical requirements, and deals with radiofrequency amplification, detection, the principles of superheterodyne receivers, automatic volume control, low-frequency amplification, and the output side. The special technique used in working with short and ultrashort waves is described, as are television, radio direction finding, and radar.

MODERN ARMS AND FREE MEN. By Vannevar Bush. Simon and Schuster, New York, N. Y., 1949. 273 pages, $8^{3}/_{4}$ by 6 inches, linen, $3.50. The work of the scientists in the last war is told from the viewpoint of the factors and developments which had to be combatted. Radar, proximity fuses, rockets, antisubmarine devices, and the atomic bomb are dealt with, including an appraisal of probable value in a future war. Radiological and biological warfare are also considered. The value of a wide range of research is brought out, and the advantages of conducting such a program in a free democracy are demonstrated. The author devotes a considerable part of the book to discussions of types of government, international relations, the nature of war and its concomitants, educational problems, and the necessity for effective planning.

(The) MATHEMATICAL THEORY OF COMMUNICATION. By C. E. Shannon and W. Weaver. University of Illinois Press, Urbana, Ill., 1949. 117 pages, diagrams, charts, tables, $9^{1}/_{4}$ by $6^{1}/_{4}$ inches, cloth, $2.50. The problem of transmission of information is dealt with from the standpoint of the prabability of the reception of the message. Two main aspects are the mathematical determination of the accuracy of message transmission under varying conditions and the analysis of channel capacity. The concept of entropy is utilized in a specialized manner in dealing with certain statistical distributions. Of the two papers included one was reprinted from *Bell System Technical Journal* of 1948. Of the other a condensation appeared in *Scientific American*, 1949.

LEGAL PHASES OF ENGINEERING: CONTRACTS AND SPECIFICATIONS. By I. C. Crawford. Macmillan Company, New York, N. Y., 1950. 346 pages, tables, $8^{1}/_{2}$ by $5^{1}/_{2}$ inches, cloth, $3.75. This textbook has three main objects: to acquaint the student with legal relations peculiar to the engineering profession and its daily business experiences; to promote an understanding of the process employed by the courts in arriving at a final decision; and to develop an appreciation of clear, concise contracts and specifications. Actual cases are used as illustrations.

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LAYOUT PLANNING TECHNIQUES. By J. R. Immer. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England; 1950. 430 pages, illustrations, diagrams, charts, tables, $9^{1}/_{4}$ by 6 inches, cloth, $5. Stressing the management approach, this text provides the basic principles of production flow and layout, methodology for solving layout problems, and a description of actual layout methods and techniques. Examples of layout from many types of manufacturing plants, offices, stores, and farms are given. A selected bibliography and a list of visual aids are included.

INTRODUCTION TO THE ENGINEERING PROFESSION, CONCERNING ENGINEERING ORIENTATION AND ENGINEERING PROBLEMS. By J. G. McGuire and H. W. Barlow. Addison-Wesley Press, Cambridge 42, Mass. 207 pages, illustrations, diagrams, charts, tables, $9^{1}/_{4}$ by $6^{1}/_{4}$ inches, cloth, $3.50. Presenting information on the principal fields and branches of engineering, together with illustrative problems, this book is of particular value to those who wish vocational guidance. The section on engineering problems presents ideas on the engineering approach to their solution and considers the basic tools of the engineer: the slide rule, logarithms, and the principles of mechanics.

ELECTRICAL MACHINERY, A PRACTICAL STUDY COURSE ON INSTALLATION, OPERATION, AND MAINTENANCE. By F. A. Annett. Third edition. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England, 1950. 458 pages, illustrations, diagrams, charts, tables, $9^{1}/_{4}$ by 6 inches, cloth, $3.75. This book covers, step by step, the installation, operation, and maintenance of electric machinery. Four new chapters in this edition deal largely with electron tubes and the circuits in which they are used. These chapters replace those on similar material in the earlier editions. Where necessary, revisions have been made to bring other parts of the text up to date. As before, the basic laws of electricity and magnetism are related to actual problems in order to show how theory fits into practice.

ELECTRONICS IN ENGINEERING. By W. R. Hill. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England, 1949. 274 pages, diagrams, charts, tables, $9^{1}/_{4}$ by 6 inches, cloth, $3.50. Designed for senior and graduate students in engineering and allied sciences, this book provides an understanding of electronics and its application to measurement and control. The treatment is analytical yet contains practical applications. The scope covers vacuum and gas-filled tubes, rectification, amplification, feedback, the cathode-ray oscilloscope, and simple control and instrumentation techniques. Problems are worked out in the text, and there are others for student solution.

ELECTRONICS: EXPERIMENTAL TECHNIQUES. (National Nuclear Energy Series Division V—Volume 1.) By W. C. Elmore and M. Sands. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England, 1949. 417 pages, illustrations, diagrams, charts, tables, $9^{1}/_{4}$ by 6 inches, linen, $3.75. Based on the work of the Electronics Group at the Los Alamos Laboratory, this volume describes the most useful and successful circuits for making nuclear and other physical measurements. In addition to the description of complete circuits, such as pulse amplifiers, counting circuits, sweep circuits, timing circuits, it contains a discussion of circuit elements. Many of the circuits described are in wide use today and provide a background for the design of new circuits.

ELECTRICAL ENGINEERS' HANDBOOK, ELECTRIC POWER (Wiley Engineering Handbook Series). H. Pender and W. A. Del Mar, editors. Fourth edition. John Wiley and Sons, New York, N. Y.; Chapman and Hall, Ltd., London, England, 1949. Paged in sections, diagrams, charts, tables, $8^{1}/_{2}$ by $5^{3}/_{4}$ inches, leather, $8.50. Seventy-one specialists have contributed to the fourth edition of this well-known handbook. In the thorough revision, increased space has been devoted to circuit stability and symmetrical components, electronic rectifiers, aircraft equipment, heat pumps, servomechanisms, permanent magnets, plastic insulating materials, and induction and dielectric treating apparatus. In addition to the comprehensive coverage of all aspects of the electric power field and related activities, basic information on mathematics and the properties of materials is included. The extensive section bibliographies have been brought up to date.

PAMPHLETS

The following recently issued pamphlets may be of interest to readers of "Electrical Engineering." All inquiries should be addressed to the issuers.

Management Control, by Dr. Alex W. Rathe. This 4-page pamphlet covers phases of managerial planning for sales, manufacturing, engineering, finance, and other corporate activities. It also includes analysis of performance in all fields of a company's operations. Copies are available at ten cents each from V. W. Palen, Bureau of Public Information, New York University College of Engineering, New York 53, N. Y.

Basic Radio Propagation Predictions for June 1950. Contains contour charts for determination of the best sky-wave frequencies over any path at any time of day. Publication number *CRPL-D67*. 16 pages. Copies can be obtained from the Superintendent of Documents, Government Printing Office, Washington 25, D. C., at ten cents each.

Superior Electrical Impregnating Varnishes to Withstand Extreme Temperature and Humidity. Impregnating varnishes, developed in research for the Signal Corps, are described in a detailed report, which appeared in the April issue of the *Technical Reports Newsletter*, issued by the Office of Technical Services. Single copies of the *Newsletter* are available from the Office of Technical Services, United States Department of Commerce, Washington 25, D. C.

An Absolute Measurement of Resistance by the Wenner Method. Describes the results of a new method which was devised for independently checking the stability of the standard of electrical resistance, in terms of length, time, and the permeability of free space. The method can detect a change of a few parts in a million in the standards used to maintain the unit. 69 pages. 30 cents a copy for residents of the United States, 40 cents a copy for residents of foreign countries. Available from the Superintendent of Documents, Government Printing Office, Washington 25, D. C.

Survey of Power Sources. A comprehensive survey of power sources in a 3-volume study covering both electric and nonelectric devices. The study is concerned with methods of generating electric power, including various prime movers suitable for this purpose. The three volumes are available as follows: Volume I, Part I, (electromagnetic generators and thermoelectric generators), 254 pages, $15.85; Volume II, Part I, (electrostatic and other specialized types of electric generators), 193 pages, $11.30; and Part II (prime movers), 226 pages, $12.50. All volumes include illustrations, tables, and graphs. Available from the Armour Research Foundation, Technology Center, Chicago 16, Ill. Microfilms of the three volumes (listed in order) as follows: *PB 98588*, $9; *PB 98589*, $7; and *PB 98590*, $8; are available from the Library of Congress, Photoduplication Service, Publication Board Project, Washington 25, D. C.

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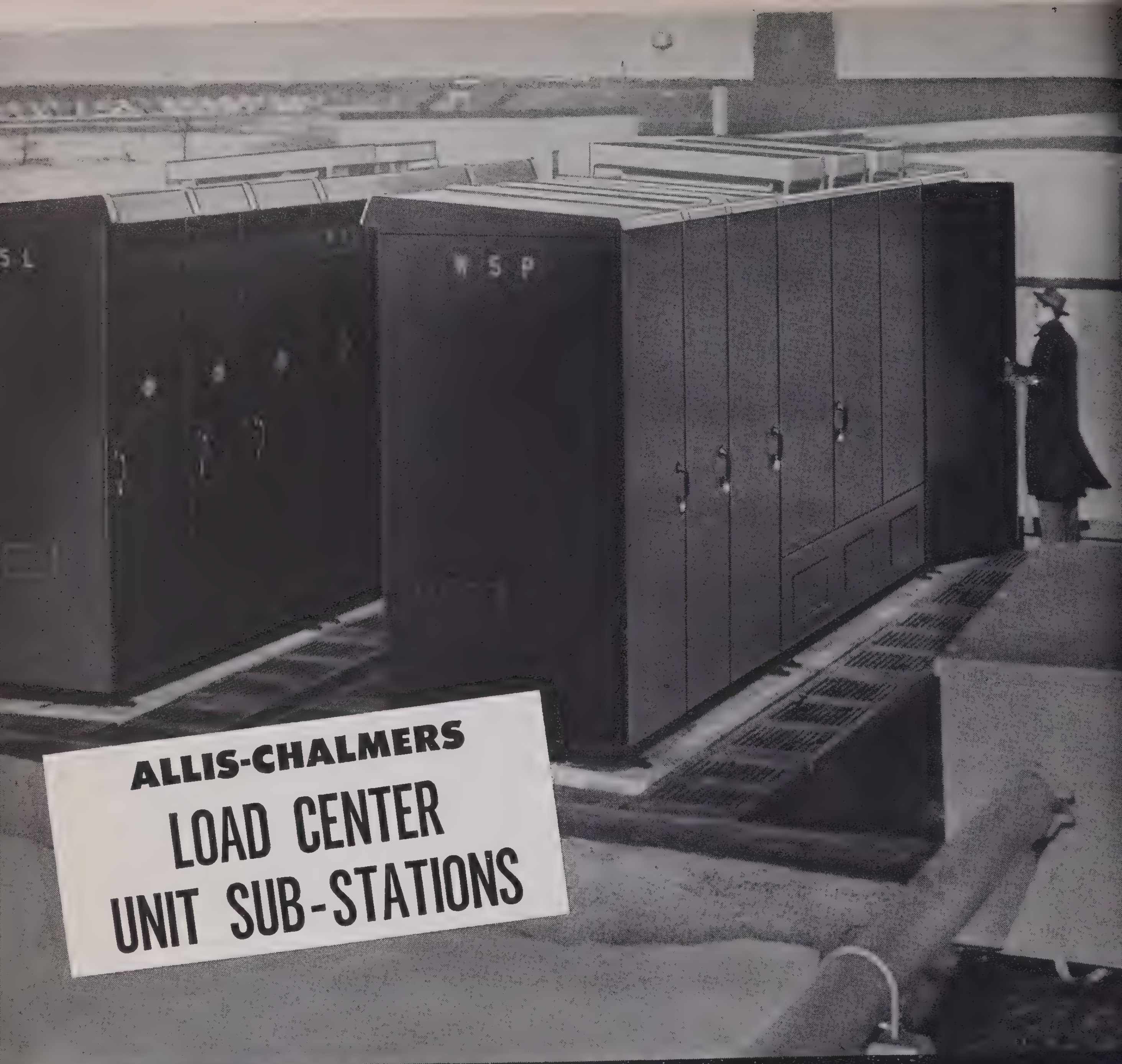

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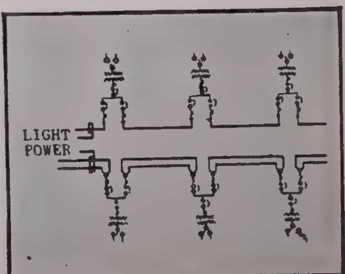

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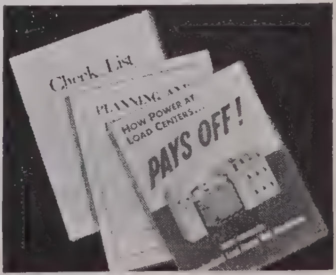

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Model S-11-A POCKETSCOPE

Vertical and horizontal channels: 0.1v rms/inch with response within —2DB from DC to 200KC. Repetitive time base continuously variable from 3cps to 50KC with + sync.

Model S-21-A Linear Time Base

Linearized periodic or trigger sweep from ½cps to 50KC. Output 20v peak with DC coupling. Positive or negative blanking signals of 100v peak. Positive and negative sync.

WATERMAN PRODUCTS CO., INC.
PHILADELPHIA 25, PA.
CABLE ADDRESS: POKETSCOPE

WATERMAN PRODUCTS INCLUDE:

S-10-B GENERAL POCKETSCOPE
S-14-A HI-GAIN POCKETSCOPE
S-14-B WIDE-BAND POCKETSCOPE
S-15-A TWIN TUBE POCKETSCOPE

Also RAKSCOPES, LINEAR AMPLIFIERS, RAYONIC® TUBES and other equipment

WATERMAN PRODUCTS

INDUSTRIAL NOTES ....

RCA Victor Appointments. The RCA Victor Division of the Radio Corporation of America has announced the appointments of R. C. Dove as operating assistant to the Vice-President, and H. V. Somerville to the position of technical assistant to the Vice-President.

Armour Research Promotes Kemp. Jay Sterling Kemp has been named Director of the Magnetic Recorder Division at the Armour Research Foundation of the Illinois Institute of Technology. Mr. Kemp was previously a research physicist and assistant director of the division.

Neon Acquires 100 Per Cent of Standard Electronics Corporation Stock. The Graybar Electric Company and Claude Neon, Inc., have jointly announced the acquisition of 100 per cent of the stock of the Standard Electronics Corporation by Claude Neon. The new wholly-owned Claude Neon subsidiary has taken over Western Electric Company's inventories of amplitude-modulation and frequency-modulation transmitting equipment, replacement parts, product designs, and drawings, and is now in a position to manufacture a line of television broadcast transmitting equipment, as well as all the equipment formerly manufactured by the Western Electric Company. The subsidiary will also service and supply replacement parts for all Western Electric broadcast transmitting equipment now in use throughout the United States. The Graybar Electric Company, which formerly distributed nationally for Western Electric, will distribute nationally for the new Claude Neon subsidiary.

Burlington Instrument News. The Burlington Instrument Company of Burlington, Iowa, has announced that the White Sales Company, 10 High Street, Boston, Mass., will represent them in the entire New England territory.

United States Testing Moves New York Offices. The United States Testing Company, Inc., has moved its New York City offices to the McGraw-Hill Building, 330 West 42d Street. The new office will be managed by Thomas C. Ridgway of the company's Service Division.

Crise Manufacturing Merges With Acro Switch. Expansion of the Crise Manufacturing Company through a merger with the Acro Switch Company has been announced. The Acro Switch Company has been moved from Cleveland, Ohio, to Columbus, Ohio, and will occupy a factory building adjacent to the Crise plant. Products will include precision snap-action switches for electric appliances, aircraft, coin machines, and electronic devices. The Crise firm has also announced purchase of the MU Switch Division from the Chase-Shawmut Corporation, Canton, Mass. The division will continue production of the MU line of electric switches. The expanded operations of the Crise Company has made it necessary to increase the number of directors from five to nine. The four new directors are: F. G. McCloskey, A. N. Winslow, Jr., A. F. Kroeger, and J. C. Harlor. Other directors re-elected are W. F. Rockwell, W. F. Rockwell, Jr., F. R. Musrush, F. P. Maxwell, and H. C. Stuckeman. W. F. Rockwell, Jr., was made Chairman of the Board.

Freyler to Manage Allis-Chalmers Mid-Atlantic Region. Frank R. Freyler has been promoted to Manager of Allis-Chalmers Mid-Atlantic Region, succeeding William Arthur, who has retired. The company has also announced that R. N. Landreth, associated with the Washington office since 1934, has been named Manager of that office.

Corning Glass to Construct New Pilot Plant. Construction has started in Corning, N. Y., on a new pilot plant, which will be used to develop manufacturing processes from basic findings, for the Corning Glass Works. Initial efforts at the new plant will be concentrated on improving television bulbs.

American Transformer Consolidates Operations. The American Transformer Company has announced completion of the consolidation of all its operations, including its general offices, under one roof in a modern building located at 285 Emmet Street, Newark 5, N. J.

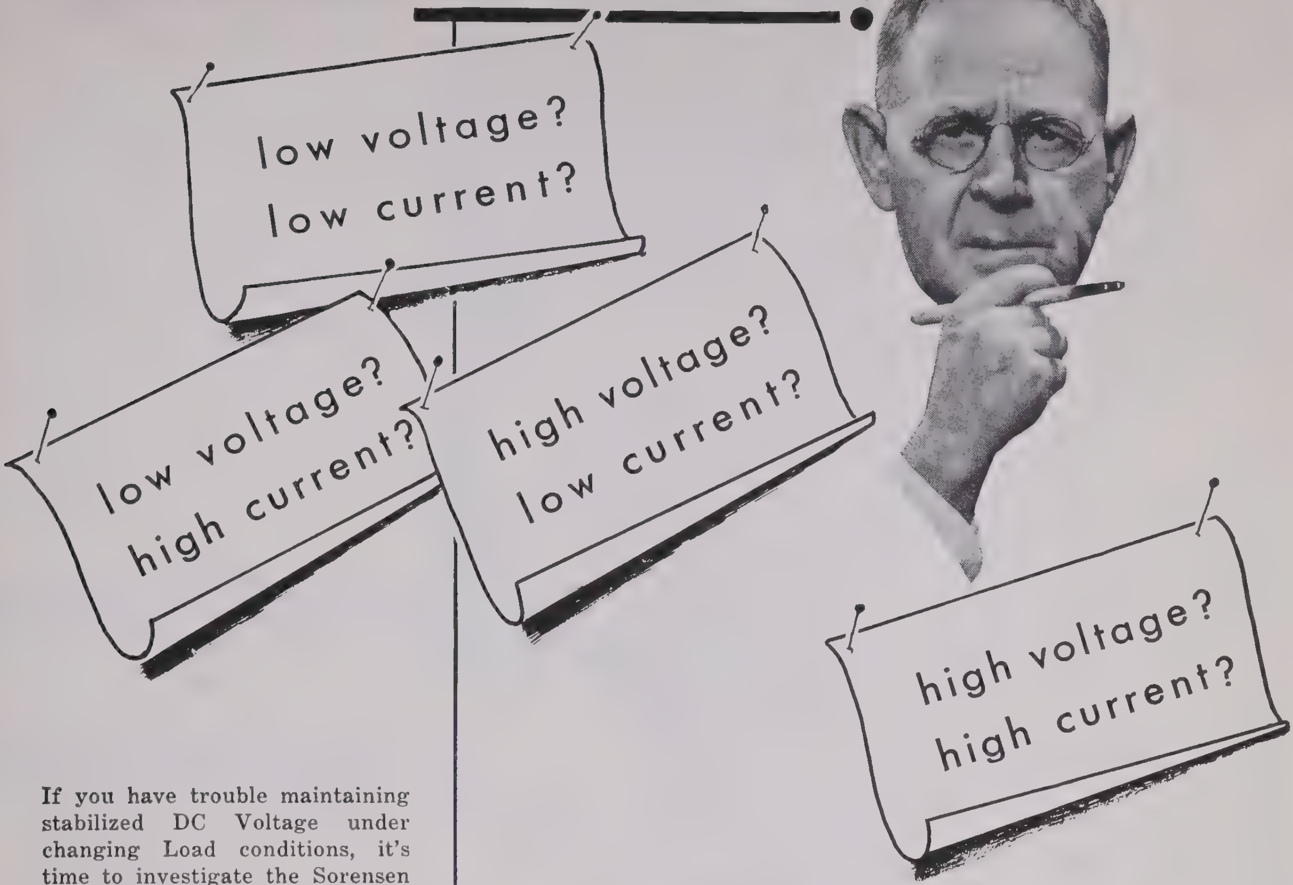
New G-E Sales Division. The General Electric Company has established a new sales division in the marketing organization of their Air Conditioning Department. The new division will be responsible for the sale and servicing of automatic heating equipment, air conditioning equipment, refrigeration machines, commercial refrigeration, and water coolers. H. M. Brundage has been appointed Manager, and Harry J. Wines, Manager of Distribution Sales.

NEW PRODUCTS ••

Diode Modulator. Designed for use in the laboratory, in television receiver production testing, and in the television service shop, the General Radio type *1000-P6* crystal diode modulator converts an oscillator, standard-signal generator, or other radio-frequency source into a test-signal generator for television receiver testing. It modulates the oscillator signal after attentuation, so that reaction on the oscillator frequency is negligible, thus producing an amplitude-modulated signal with no significant incidental frequency modulation. Range of modulating frequencies is zero to five megacycles and carrier frequency range is 20 to 1,000 megacycles, covering the proposed new ultrahigh-frequency television bands. Im-

(*Continued on page 22A*)

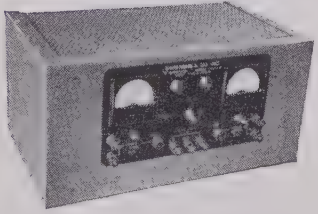
what's the REAL PROBLEM?


low voltage?
low current?
low voltage?
high current?
high voltage?
low current?
high voltage?
high current?

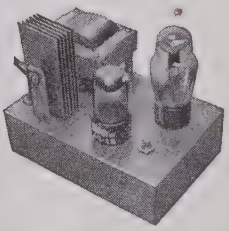
If you have trouble maintaining stabilized DC Voltage under changing Load conditions, it's time to investigate the Sorensen line of Nobatrons.

- **Common Nobatron Specifications:** Regulation Accuracy 0.2% from 0.1 load to full load; Ripple Voltage 1%; Recovery time 0.2 seconds under most severe change in load or input conditions; 95-130 VAC single phase 50-60 cycles: adapter available for 230 VAC operation.
- **Ratings**
  Nobatron — 6, 12, 28, 48, 125 volts from 5-350 amperes.
  B-Nobatron — 325, 500, 1000 volts — 125 ma.; 300 ma. & 500 ma.
  DC Standards — 2, 6, 15, 25, 50, 75, 150, 300 volts — 15, 30 and 50 ma.
- **Problems?** Sorensen Engineers are always at your service to help solve unusual applications.

TYPICAL DC SOURCES

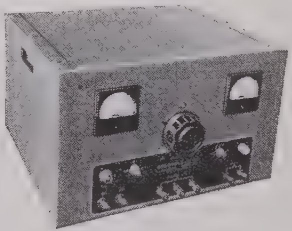


MODEL 325B
0-325 volts; 125 ma.



MODEL VS-50-50
50 volts @ 50 ma.

MODEL E-6-15
6 volts; 1.5-15 amperes



MODEL 500 B
0-500 volts; 300 ma.

WRITE TODAY For Catalog B1049 For The Complete Line And Prices.

POWER controlled converted

Sorensen and company, inc.
375 FAIRFIELD AVE. • STAMFORD, CONN.

MANUFACTURERS OF AC LINE REGULATORS, 60 AND 400 CYCLES; REGULATED DC POWER SOURCES; ELECTRONIC INVERTORS; VOLTAGE REFERENCE STANDARD; CUSTOM BUILT TRANSFORMERS; SATURABLE CORE REACTORS

STRUTHERS DUNN

Military Type MINIATURE MULTI-POLE D-C RELAY

Here are miniature, low wattage d-c relays that really stand up under extreme conditions of shock and vibration. False contact operation is avoided without sacrificing desirable electrical characteristics—and at no extra relay cost. Available in any contact arrangement up to 4-pole double-throw. Open, plug-in base, metal encased or hermetically-sealed types. Write for Bulletin L2610.

STRUTHERS-DUNN, INC.
150 N. 13th St., Philadelphia 7, Pa.

BALTIMORE • BOSTON • BUFFALO • CHARLOTTE • CHICAGO • CINCINNATI CLEVELAND • DALLAS • DETROIT • KANSAS CITY • LOS ANGELES • MINNEAPOLIS • MONTREAL • NEW ORLEANS • NEW YORK • PHILADELPHIA • PITTSBURGH • ST. LOUIS • SAN FRANCISCO • SEATTLE • SYRACUSE • TORONTO

(*Continued from page 16A*)

pedance is 50 ohms for radio-frequency circuits, and coaxial 50-ohm attenuators are available. Further information on the diode modulator is available from the General Radio Company, 275 Massachusetts Avenue, Cambridge 39, Mass.

Alternating Voltage Supply. The Sola Electric Company, 4633 16th Street, Chicago 50, Ill., has announced a new voltage supply, the "Solavolt" type "*CVL.*" Solavolts are designed for use with equipment that requires an adjustable source of constant alternating voltage (from zero to 130 volts) of undistorted wave shape. Voltage stabilizing characteristics are ± 1-per cent for line input changes from 95 to 125 volts, with less than 3-per cent harmonic distortion of the input voltage wave. Each Solavolt is provided with a receptacle for a fixed, regulated 115 volts; a receptacle for a variable, regulated output of zero to 130 volts; and a pair of jacks with regulated, variable output of zero to 130 volts for connecting instruments with plugs or wire-type leads. Technical bulletin *CVL-140* is available upon request from L. G. Warren, of the Sola Electric Company.

Diameter Control Cable. Rockbestos *PNR* is a small 600-volt control cable with a conductor operating temperature of 168 degrees Fahrenheit or 75 degrees centigrade. It is 25- to 30-per cent smaller and 10- to 15-per cent lighter than conventional types of control cables, with a high dielectric strength which breaks better than 40 times the operating voltage. The cable is constructed of individual conductors made of stranded tinned copper number *12 AWG* 19/25 extruded with $16^{1}/_{2}$ mils of polyethylene or number *9 AWG* 9/22 extruded with a 20-mil polyethylene wall. Four mils of extruded nylon are used over the polyethylene, and over that, extruded Rockhide, which means that these cables can be laid directly in acid or alkaline soils, or used where subjected to weather, sunlight, chemical fumes, oil, grease, or alcohol. Further information on *PNR* may be obtained from the Rockbestos Products Corporation, New Haven 4, Conn.

Superspeed Projector. The Television Transmitter Division of Allen B. Du Mont Laboratories, Inc., 2 Main Avenue, Passaic, N. J., has announced a new Du Mont-Holmes "Superspeed" projector for television. The intermittent sprocket of the new projector pulls down in approximately 2,000 microseconds, thus reversing the present light-duty cycle and allowing pulldown during the blanking period of the tube. This 2,000-microsecond pulldown characteristic makes the projector a dual-purpose tool for the television station—first, as a direct projector for image orthicon camera pickup, providing a film chain free from the spurious signal and shading problems in present iconoscope pickup chains. Since the

(*Continued on page 32A*)

Cut Installation Costs

WITH 30% SMALLER ROCKBESTOS A.V.C.®

USE A SMALLER CABLE!

With a 230 ampere load you use Size 000 A.V.C. instead of 300 MCM RH*.

SAVE ON CONDUIT!

You use 2-inch conduit rather than 2½-inch conduit.

SAVE ON FITTINGS!

You use smaller fittings—bushings, couplings, terminators, connectors, etc.

SAVE ON LABOR!

Because the cable is lighter, smaller, you can pull it through the conduit easier, faster, and, of course, *cheaper.*

The more efficient current carrying capacity of Rockbestos A.V.C. means plenty of savings for you. Write for the booklet "Cut Current Carrying Costs."

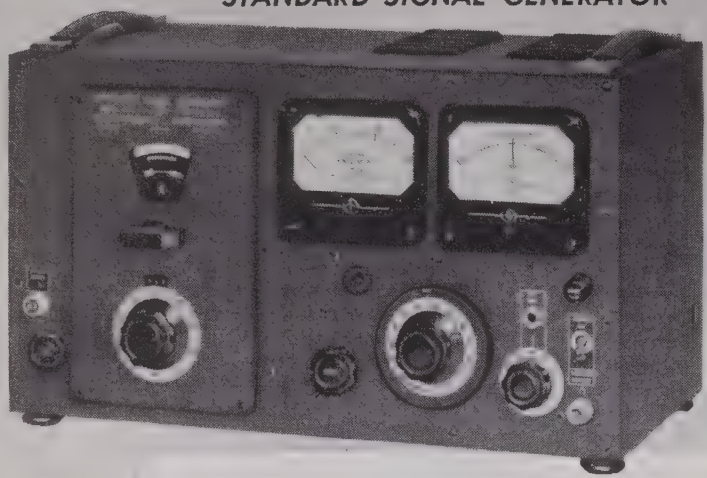
*Comparison with Type RH, 3 conductors in conduit, 40°C — (104°F). See Chapter X, National Electrical Code.

ROCKBESTOS PRODUCTS CORPORATION
New Haven 4, Conn. • New York • Cleveland • Chicago • Detroit
Pittsburgh • St. Louis • New Orleans • Los Angeles • Oakland, Calif.

Hi ...*Your best buy*

*Rockbestos A.V.C. has a Higher Ampere Rating

MEASUREMENTS CORPORATION *MODEL 80*
STANDARD SIGNAL GENERATOR



2 to 400 MEGACYCLES

MANUFACTURERS OF
Standard Signal Generators
Pulse Generators
FM Signal Generators
Square Wave Generators
Vacuum Tube Voltmeters
UHF Radio Noise & Field Strength Meters
Capacity Bridges
Megohm Meters
Phase Sequence Indicators
Television and FM Test Equipment

MODULATION: Amplitude modulation is continuously variable from 0 to 30%, indicated by a meter on the panel. An internal 400 or 1000 cycle audio oscillator is provided. Modulation may also be applied from an external source. Pulse modulation may be applied to the oscillator from an external source through a special connector. Pulses of 1 microsecond can be obtained at higher carrier frequencies.

FREQUENCY ACCURACY ±.5%

OUTPUT VOLTAGE 0.1 to 100,000 microvolts

OUTPUT IMPEDANCE 50 ohms

MEASUREMENTS CORPORATION
BOONTON NEW JERSEY

WRITE FOR 80-PAGE MANUAL

ILSCO
CONNECTORS—ACCESSORIES
Here is a mere handful of the thousands of SPECIAL CONNECTORS we design and make for the electrical industry.

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If YOU have a
SPECIAL PROBLEM
put it up to the Ilsco Engineers. We'll solve it for you. No obligation, on your part.
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CINCINNATI 27, O.

(*Continued from page 32A*)

have been incorporated. The control lead terminal box has been relocated to insure greater safety when checking terminals. Synthetic flameproof wire, and a new short-circuiting link added to the current transformer secondary are other improvements. Engineering details of the voltage regulators are given in bulletin *01B6056C*. Both bulletins are available from the Allis-Chalmers Manufacturing Company, 931 South 70th Street, Milwaukee, Wis.

Radio Interference Locator. A new radio interference locator for the 550-kc to 30-megacycle frequency range has been made available by the Sprague Products Company, North Adams, Mass. Designed specifically for use by public utility trouble-shooters and others interested in power-line preventive maintenance work, the Sprague model *302* locator utilizes a sensitive 8-tube superheterodyne circuit and operates either from self-contained batteries or 115-volt mains. Each locator is supplied with both a loop and a collapsible rod antenna for normal use. A radio-frequency search probe, insulated for 35,000 volts alternating current, is also available for field use as an audio probe for circulating current faults and cable fault location. A complete description of the instrument is given in Sprague bulletin *M-446*, available upon request to the company.

TRADE LITERATURE

Care of A-C Rotating Equipment. To promote intelligent and consistent maintenance of electric machines, Allis-Chalmers is making available in booklet form a series of articles by Fraser Jeffrey, assistant to the company's chief electrical engineer, entitled "Care of A-C Rotating Equipment." Contents of the 24-page booklet are broken down broadly into preventive maintenance and machine repairs. Subjects covered are drying moist insulation, measuring insulation resistance, bearing clearances, proper machine applications, stator coil and slip ring rotor repairs, and balancing of rotating equipment. Copies of the booklet, *05R7417*, are available upon request from Allis-Chalmers Manufacturing Company, 931 South 70th Street, Milwaukee, Wis.

Silent Sentinels. A newly revised edition of "Silent Sentinels," a 236-page reference book devoted to protective relays, has been published by Westinghouse. This latest edition records the growth of the relay art to date, including the most recent developments in the design and application of protective relays and relaying systems. The book is divided into two parts; the first dealing with the application of protective relays, and the second with the equipment itself. "Silent Sentinels" can be obtained by writing the Westinghouse Electric Corporation, P. O. Box 2099,

(*Continued on page 50A*)

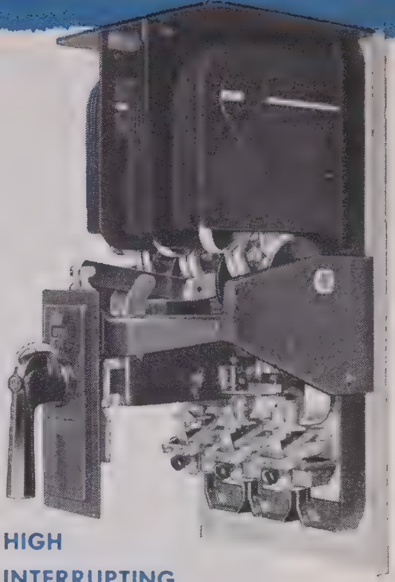
get Extra Protection– SPECIFY I-T-E MULTUMITE SWITCHGEAR!

I-T-E Multumite Switchgear is specially designed o provide the *extra margin of safety* so necessary to uninterrupted service of electrical circuits. Metal-enclosed Multumite Switchgear assures positive protection of secondary distribution systems. *Here are some reasons why:*

1. Breaker's metal panel separates bus and breaker compartment, seals off ionized gases.
2. Silver-plated buses and connections eliminate progressive oxidization, minimize temperature rise.
3. Easy accessibility of breakers and bus compartments facilitates inspection and maintenance.
4. Enclosure of control wiring in metal troughs provides a new degree of safety and protection.
5. Specially designed arc chutes quench arcs *quickly* and dependably, *in air.*
6. Breakers are mechanically and electrically trip-free.

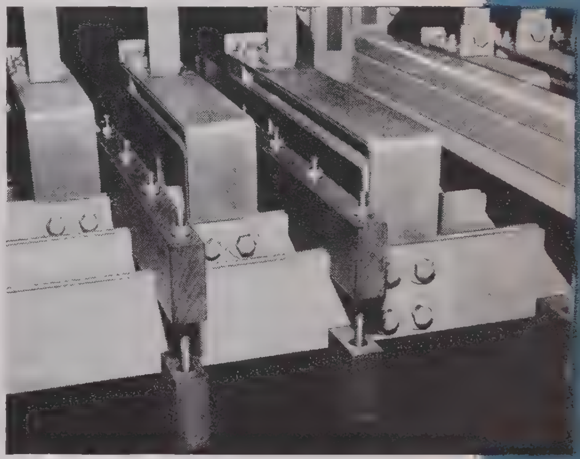
These examples of extra quality—extra protection built into I-T-E Switchgear are typical. Investigate the others.

All I-T-E Switchgear assemblies offer the benefits of an application planned for your specific needs, with units coordinated for most effective protection. Quick, easy installation is assured. *Complete* assembly is tested *before* shipment. Quality is fully guaranteed.



HIGH INTERRUPTING CAPACITY BREAKERS

TYPE KB Breaker. 25,000 RMS Amp. Interrupting Rating. 600 Amp. Continuous Rating. 2, 3, or 4 Poles. Manually or electrically operated.



IDEAL BUS ARRANGEMENT

MULTUMITE BUS is arranged for adequate electrical clearance. Strong bracing with sturdy insulating supports assures withstanding maximum short circuit stresses. Bolted connections provide solid contact and rigidity.

For *more dependable* Switchgear

— *specify I-T-E!*

I-T-E Circuit Breaker Company • 19th & Hamilton Streets • Philadelphia 30, Pa.
Power Switching Equipment: Railway and Industrial Engineering Co., Greensburg, Pa.
Canadian Mfg. & Sales: Eastern Power Devices, Ltd., Toronto • Export Sales: Philips Export Corp., New York

SWITCHGEAR • UNIT SUBSTATIONS • ISOLATED PHASE BUS STRUCTURES • CIRCUIT BREAKERS • MECHANICAL RECTIFIERS
RESISTORS • SPECIAL PRODUCTS

AUTOMATIC
FLOATING TYPE
BATTERY CHARGER

FOR 60-CELL
CONTROL BATTERIES

PEC-626

...gives you extreme accuracy and exceptional reliability

EXPRESSLY DESIGNED for unattended station service, the PEC-626 Automatic Battery Charger provides the extreme accuracy of electronic control plus the exceptional reliability demanded by this type of service.

In designing this unit, Power Equipment Company engineers started with the rugged components of a manual charger, added a magnetic system for coarse voltage control, then a simplified electronic system for fine voltage control.

The PECO Charger accurately floats the control battery of any power station or substation which has a reasonably constant switchboard load; furnishes power to the load and maintains a fully charged battery, ready for any emergency. DC output is sufficient to continuously charge 60 lead acid battery cells at 129 volts, at a maximum rate of 12 amperes, and is automatically regulated to within ±0.5 percent, for AC line voltage fluctuations of ±5 volts on a 230 volt circuit.

Exceptional reliability is shown by the fact that if the electronic control section should be disconnected, the magnetic control section will still automatically hold the output voltage to within ±3 percent of nominal voltage.

Write for specifications now!

POWER EQUIPMENT Company

Battery Chargers ☆ Battery Eliminators ☆
D.C. Power Supply Units ☆ Regulated Exciters
☆ and other Special Communications Equipment

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(*Continued from page 40A*)

Pittsburgh 30, Pa. In quantities up to 19 copies, a price of $3.00 has been established, while if 20 or more are ordered, each sells for $2.70. Educational institutions can buy up to nine copies at $3.00 each, and ten or more for $2.00 each. All prices are net, postpaid.

40 Uses for Germanium Diodes. A new booklet, well illustrated with typical circuits for 40 basic germanium diode applications, has been published by the Electronics Division, Sylvania Electric Products, Inc., 1740 Broadway, New York 19, N. Y. Text of the booklet is grouped into three sections: receivers and receiver applications; transmitter and amplifier applications; and instruments and gadgets. The booklet also includes adequate descriptions and circuit diagrams for many easy-to-build devices for the modelmaker and experimenter. The booklet, "40 Uses for Germanium Diodes," may be obtained from authorized Sylvania Radio tube distributors or from the Advertising Department, Sylvania Electric Products, Inc., Emporium, Pa., for the price of $1.00.

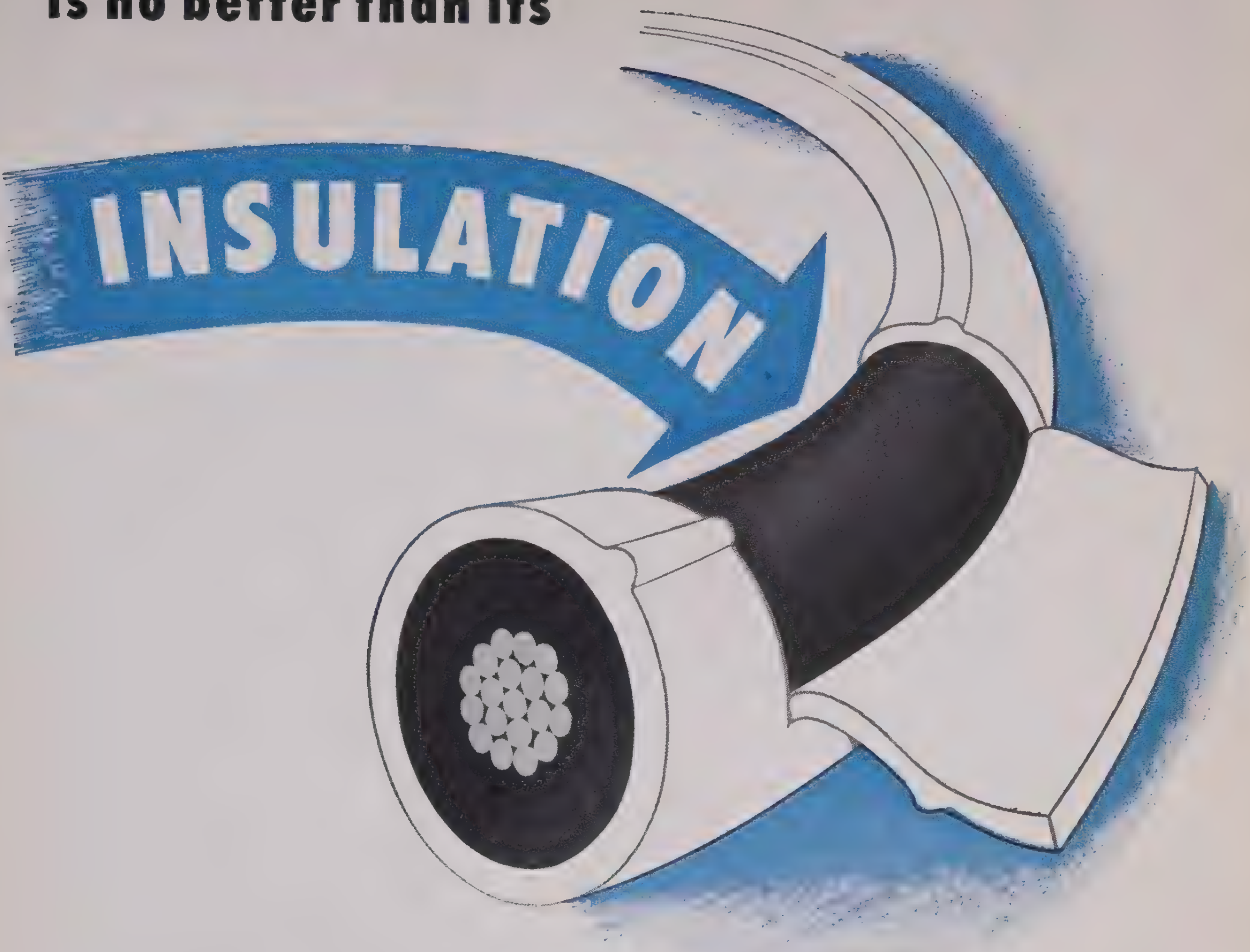
X-Y Recorder. To provide information about their new high-speed curve-plotting recorder which is valuable in research and routine investigations for drawing the relationship between two functions, Leeds and Northrup has issued an illustrated folder describing its new Speedomax X-Y recorder. A copy of the folder, *EM9-420(1)*, may be obtained upon request from the Leeds and Northrup Company, 4934 Stenton Avenue, Philadelphia 44, Pa.

Cannon Plugs. A revised 48-page engineering bulletin on the Cannon Electric Types K and RK connector series has been issued, which contains complete technical data on the entire line. Copies are available from Cannon Electric Development Company, 3209 Humboldt Street, Los Angeles 31, Calif.

"How to Run a Lathe." The revised 49th edition of the lathe operator's handbook, "How to Run a Lathe," has just been published. A paper-bound copy of the 128-page book is available for $0.25, or $1.00 for an imitation leather cover. Orders should be sent to the South Bend Lathe Works, South Bend 22, Ind.

Branch Circuit Overcurrent Protection. The Chase-Shawmut Company of 364 Merrimac Street, Newburyport, Mass., has announced publication of a bulletin based on the latest proposal for circuits of 30 amperes and less, prepared by the Edison Electric Institute–Association of Edison Illuminating Companies Joint Committee on Branch Circuit Protection. A feature of the bulletin is a graphic comparison between curve G-5 of the EEI-AEIC proposal (time-current characteristics and tolerances for recommended 20-ampere protective devices) and the performance curve of the Shawmut C-quick fuse with time-delay. For a copy write to the company.

an electrical cable is no better than its



An electrical cable is only as efficient and long-lasting as its insulation. You will find true cable economy *only* in the cable with the best insulation. Because electrical insulation is so vital to cable performance, it is important to know what makes one type of insulation better than another.

There are three basic factors determining the electrical and mechanical characteristics of rubber cable insulation.
1. The type and grade of rubber used in the compound.
2. The method of applying the insulation to the cable.
3. The method of vulcanizing the insulation.

In Okonite insulations, each of these three points is a reason for superior performance. First, Okonite uses only Wild Up-River Fine Para rubber – the very finest obtainable – because this rubber has proved during more than 70 years of actual use to have better dielectric and aging qualities than any other.

Second – the unique Okonite strip method of applying insulation assures absolute uniformity of wall thickness . . . perfectly centered conductors. This advantage, guaranteed only by the strip method, is another reason for the famous long life and dependability of Okonite-insulated cables.

Third – after the insulation has been applied by the strip method, it receives a *single* vulcanization in a continuous tin mold, under high pressure. Advantages of this exclusive process are an insulation of higher density, greater physical and electrical uniformity.

Years of operation under widely varied conditions – the most convincing test of all – *prove* the longer life and more dependable performance you obtain from an Okonite insulation. The Okonite Company, Passaic, N. J.

8107

THE BEST CABLE IS YOUR BEST POLICY

OKONITE SINCE 1878 **insulated wires and cables**

A New Fuse FOR THE NEW FUSING CONCEPT—

ANNOUNCING AT THIS TIME additional voltage ratings, a choice of time-current characteristics, and other important new features, we remind you that the SMD-2 is a modern fuse so far advanced in design that the present concepts of high voltage fuse application must be expanded if full advantage is to be taken of the economy inherent in fuse protection of transmission and sub-transmission systems.

* **FULL COVERAGE PROTECTION IS:** the new concept of transformer fusing in which:

❶ A primary fuse is applied for both primary short circuit and secondary back-up short circuit protection.

❷ A fuse is expected to perform dependably regardless of type of system; type of fault current; type of application; or system and atmospheric conditions.

* **FULL COVERAGE PROTECTION PROVIDES—** along with the above protection—savings in operating expense by:

❶ Eliminating the need for replacement of "suspect" fuses on other phases when one fuse blows.

❷ Eliminating the need for periodic replacement of fuses to prevent "sneak-outs" caused by vibration- or age-weakened fusible elements.

* **FULL COVERAGE PROTECTION REQUIRES:**

Ⓐ dependable high and low fault-current interrupting ability;

Ⓑ protection against dielectric breakdown or external flashover from severe recovery voltage;

Ⓒ a fine degree of accuracy in time-current characteristics;

Ⓓ a "non-damageable" fusible element which cannot be injured by surge currents, vibration, or aging;

Ⓔ a choice of time-current characteristics to provide flexibility in coordinating with other primary, and with the secondary, protective devices.

The SMD-2 offers short circuit interrupting capacity many have thought could only be obtained with a circuit breaker; yet it is more reliable than a breaker. And the SMD-2 costs so much less that economic necessity need no longer compel a choice between the expense of a breaker or the often used expedients of solid tie, grounding switches, or remote-trip-relay protection, when tapping transmission and sub-transmission lines.

Permanent accuracy of the SMD-2 time-current characteristics permit sufficiently close fusing of the transformer bank to get back-up protection in case of secondary bus faults or failure of secondary protective devices—and this protection is accomplished without incurring outages caused by unwanted fuse operations.

The importance of fusing for secondary protection has been demonstrated by field experience which has shown that more than half of the operations of fuses thus applied were caused by secondary faults that most certainly would have damaged or destroyed the transformers. With the SMD-2 this valuable secondary protection is obtained in addition to a full measure of primary protection.

SMD-2 HIGHLIGHTS

Voltage Range: 34,500 to 138,000.

Interrupting Ratings: to 1,000,000 KVA.

In fuses of low ampere ratings, low fault currents are positively interrupted by an auxiliary gas-blast arc extinguisher.

Drop-out release is protected against opening from vibration or shock by a floating, self-aligning, latch mechanism.

Drop-out, when intended, is assured by a powerfully spring driven pry out lever, and a "wiping-in, rolling-out" contact design.

Initial and permanent accuracy of time-current characteristics are provided by non-damageable fusible elements.

For a complete account of this new protective device you should have the new Catalog Section 262, now ready. Write for a copy today!

S&C ELECTRIC COMPANY

Formerly SCHWEITZER & CONRAD, INC.

Full Coverage

SMD-2 DROP OUT POWER FUSE

NEW CATALOG

SECTION 262

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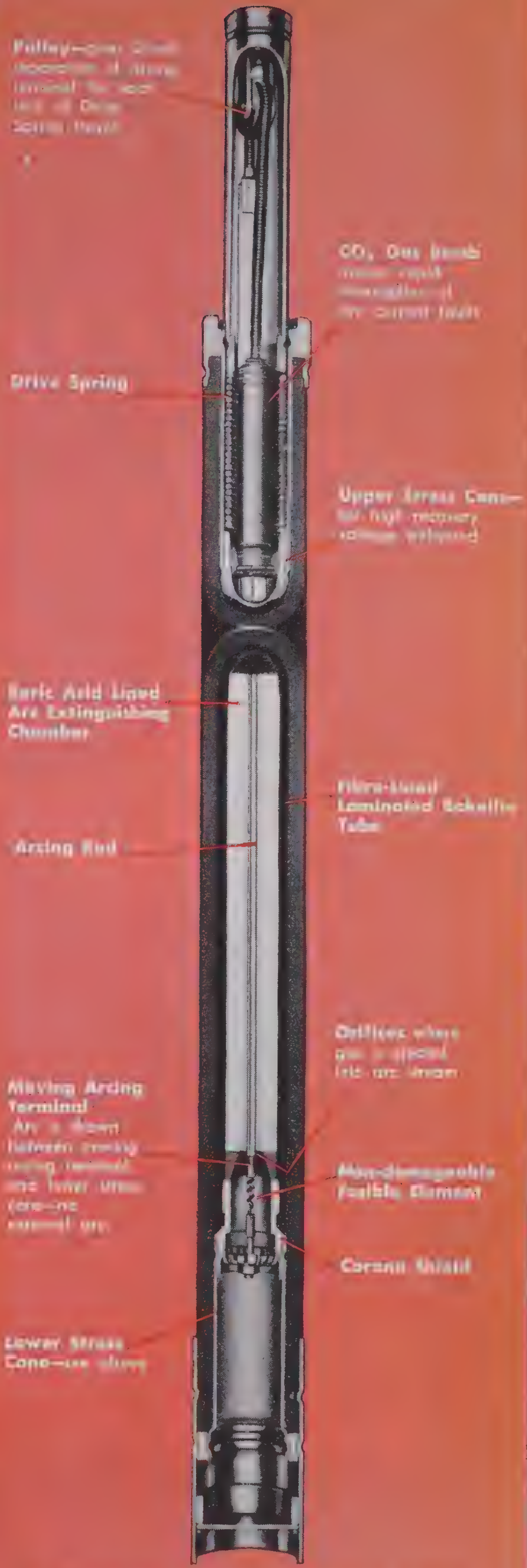
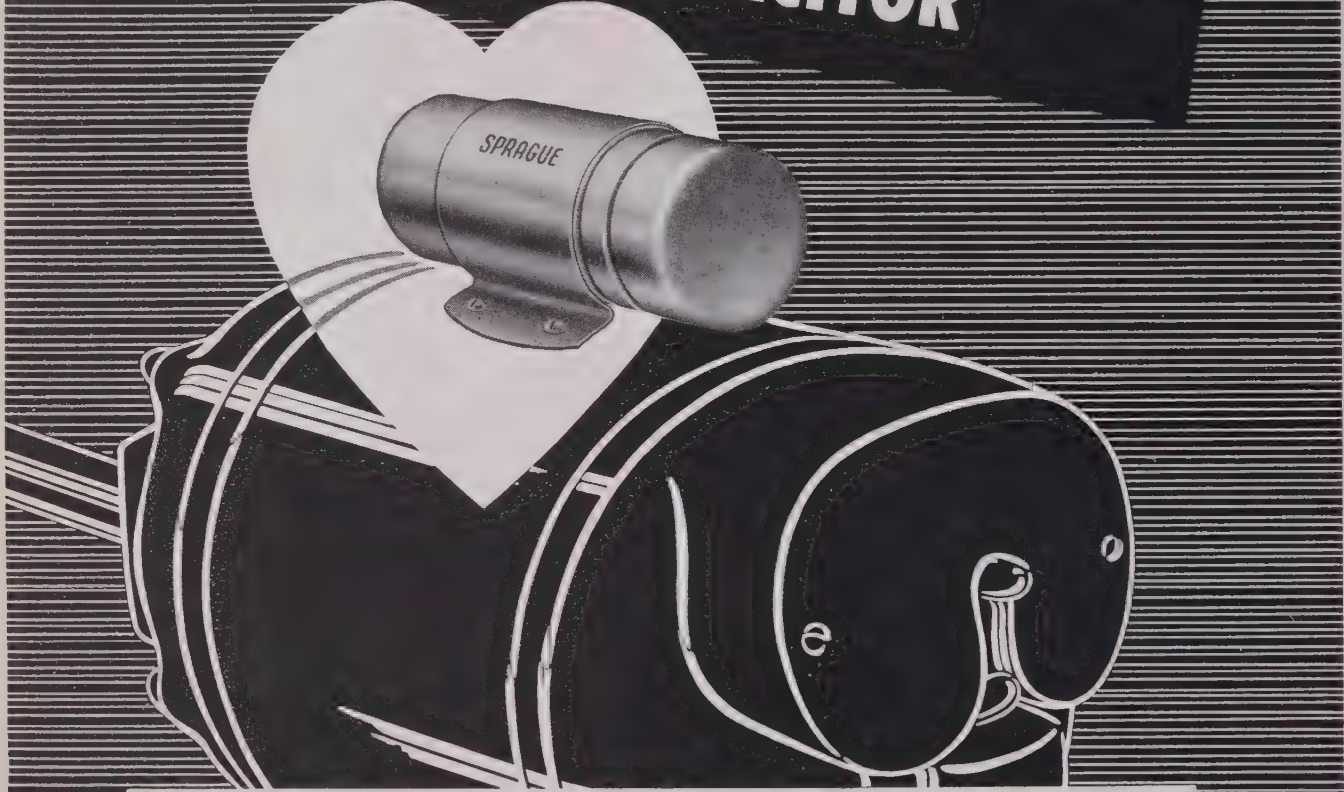


CUTAWAY VIEW OF FUSE UNIT

The HEART of the START
is a
SPRAGUE
A-C MOTOR-STARTING
CAPACITOR



For day-in, day-out dependability in hundreds of thousands of starts . . .

For outstanding reliability that spells freedom from costly service and consumer complaints on a-c motor-driven appliances and equipment . . . ***Specify Sprague A-C motor-starting capacitors!***

Available in both metal and plastic cases, with mounting hardware for any application. Capacitance ratings for motors as high as 7½ horsepower.

Sprague application engineers will be glad to assist you in analyzing specific capacitor problems.

Write for sample request form and catalog.

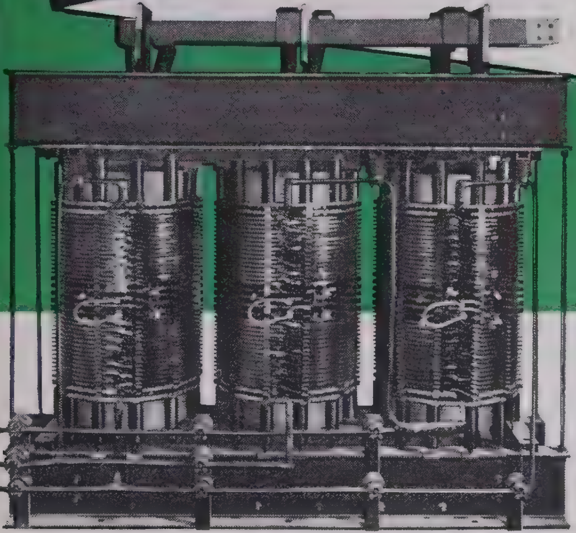
SPRAGUE

SPRAGUE ELECTRIC COMPANY
North Adams, Massachusetts

PIONEERS IN
ELECTRIC AND ELECTRONIC DEVELOPMENT

DRY-TYPE TRANSFORMERS REQUIRE EXCEPTIONAL INSULATION

Sorgel USES NATVAR FIBERGLAS*



Core and coil assembly of a Sorgel 1500 kva., 3 phase, 12,500 volt air-cooled transformer ready for mounting in the steel enclosure of a unit sub-station. Coils are disc type, separated and supported by steatite spacers. It is built to operate at temperatures up to 80°C. above normal ambient. Natvar Varnished Fiberglas and Varnished Fiberglas Sleeving are used to insulate coils and leads. Natvar Varnished Fiberglas Tape is used for extra end turn insulation.

Air-Cooled, Dry-Type Transformers are built by Sorgel Electric Company, Milwaukee, to meet the increasing demand for large distribution transformers that can be installed *inside* buildings as unit sub-stations without construction of fireproof vaults.

Transformers are housed in compact steel enclosures together with the necessary switches, meters and circuit breakers. They take up very little space, and can be placed at load centers, eliminating long secondary feeders and improving plant layout.

Natvar Varnished Fiberglas, Varnished Fiberglas Tapes and Varnished Fiberglas Sleeving are Class B insulation, approved for 85°C. temperature rise. All Natvar flexible insulations are consistently uniform, no matter when or where purchased. They are immediately available either from your wholesalers' stocks or direct from our own.

*FIBERGLAS is the trade-mark (Reg. U.S. Pat. Off.) of Owens-Corning Fiberglas Corporation for a variety of products made of or with glass fibers.

Natvar

Natvar Products

- Varnished cambric—straight cut and bias
- Varnished cable tape
- Varnished canvas
- Varnished duck
- Varnished silk
- Varnished special rayon
- Varnished Fiberglas cloth
- Silicone coated Fiberglas
- Varnished papers
- Slot insulation
- Varnished tubings and sleevings
- Varnished identification markers
- Lacquered tubings and sleevings
- Extruded vinyl tubing and tape
- Extruded vinyl identification markers

Ask for Catalog No. 21

THE NATIONAL VARNISHED PRODUCTS *Corporation*

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CABLE ADDRESS
NATVAR: RAHWAY, N. J.

203 RANDOLPH AVENUE ★ WOODBRIDGE, NEW JERSEY

*Patents applied for

- VSWR less than 1.2 at all frequencies to 3000 mc.
- **Turret Attenuator*** featuring **"Pull — Turn — Push"** action with 0, 10, 20, 30, 40, 50 DB steps.
- Accuracy ± .5 DB, no correction charts necessary.
- 50 ohm coaxial circuit. Type N connectors.

Inquiries are invited concerning single pads and turrets having other characteristics

STODDART AIRCRAFT RADIO CO.
6644 SANTA MONICA BLVD., HOLLYWOOD 38, CALIFORNIA
Hillside 9294

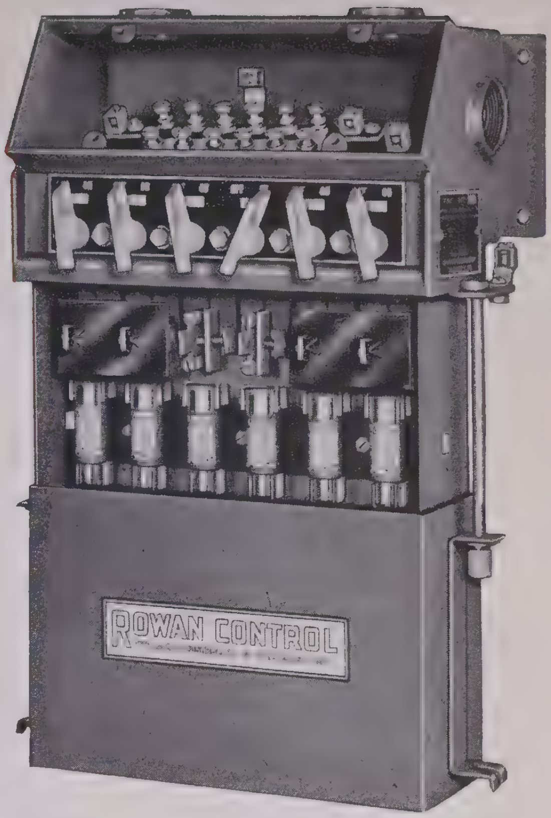
ROWAN TYPE 800--834

LIGHTING SWITCH

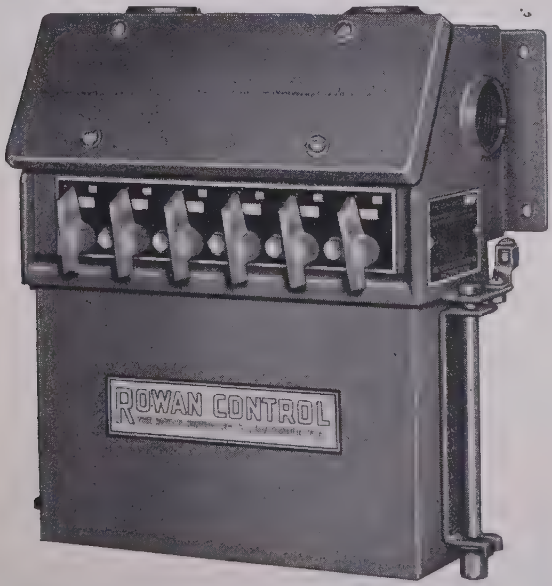
OIL IMMERSED

Compact in design, positive in operation, ruggedly constructed to give long, trouble-free service—Rowan Type 800-834 oil immersed lighting switches are "first choice" for locations where operating requirements are severe and atmospheric conditions may be dusty, corrosive or semi-hazardous. They are available in 6- and 12-gang units—easy to install since all wiring and bus work to the central terminal board is done at the factory—easy to inspect since the entire mechanism of the switch is readily accessible.

Extra heavy, self-aligning, quick make and quick break, constant pressure, renewable contacts are series break which minimizes concentration of burning. Rowan time-tested AIR-SEAL fuses provide thoroughly dependable short circuit protection.



Type 834, 6-gang, single circuit Lighting Switch with oil tank lowered showing arrangement of component parts.



Type 834, 6-gang, single circuit Lighting Switch with oil tank in closed position.

Enclosures are designed to meet the requirements of NEMA Type XI. They are of welded construction—fabricated from heavy, high quality steel sheets with threaded conduit openings.

Type 800 for use on 3-wire, single phase, 115/230 V. circuits.

Type 834 for use on 3-phase, 4-wire, 120/208 V. circuits.

ROWAN CONTROL

THE ROWAN CONTROLLER CO., BALTIMORE, MD.

THIS PORTABLE RECORDER COMBINES··

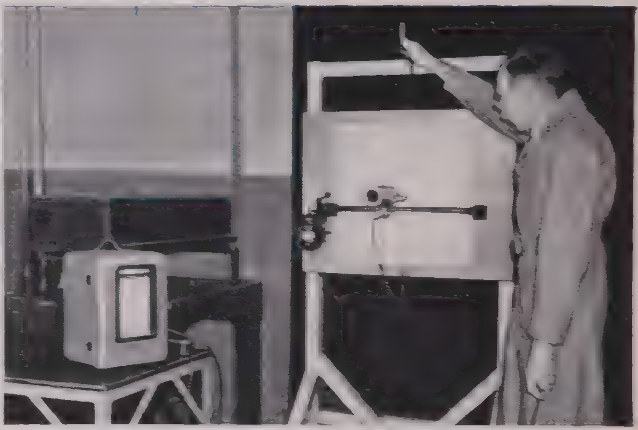
Speed
Accuracy
Flexibility

Type CE Photoelectric Recorder

General Electric's CE Photoelectric Recorder is ideal for many types of research programs because it combines the convenience of compact, portable construction with a sensitivity and versatility far beyond the range of ordinary recording instruments.

In addition to measuring a-c and d-c volts and amperes, the CE will record almost anything that can be measured with an indicating instrument. Chart speeds range from 1/2 inch to 72 inches per minute; sensitivities are as great as 1.0 microampere full scale; response periods as fast as 1/5 second for full-scale deflection.

Put the CE Photoelectric Recorder to work in YOUR laboratory. Contact your General Electric representative for details, or write for bulletin GEC-254. Apparatus Dept., General Electric Co., Schenectady 5, N. Y.



From the Laboratory of National Carbon Division, Union Carbide and Carbon Corporation, comes the story of experiments designed to test various types of positive carbon craters which are used in carbon arc lamps. An important component of the test set-up is General Electric's Type CE Photoelectric Recorder. It provides the company's scientists with an accurate record of the light intensity of the carbon under test. The light, picked up by a photocell, is recorded by the CE Recorder in microampere readings which are calibrated in foot-candles.

THE CE RECORDER IS THE *ONLY* POTENTIOMETER RECORDER THAT GIVES YOU PORTABILITY, FAST-RESPONSE, MULTIPLE RANGES AND HIGH SENSITIVITY

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World's Largest Stock of

Ready for ***IMMEDIATE*** *Shipment*

For fast delivery, rely on Ohmite. Stock orders are usually shipped out the same day received. Special orders, too, are scheduled and shipped promptly.

How can Ohmite do it? First, they have developed an efficient, tightly geared order system which short-cuts red tape.

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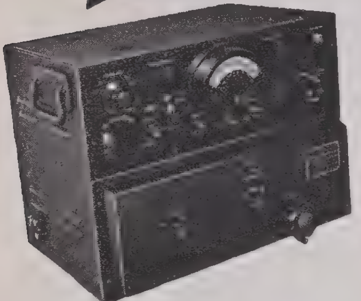
RHEOSTATS RESISTORS TAP SWITCHES

STANDARD RI-FI* METERS

14kc to 1000mc!

DEVELOPED BY **STODDART**
FOR THE ARMED FORCES.

AVAILABLE COMMERCIALLY.



VHF!

15 MC
to
400 MC

NMA - 5

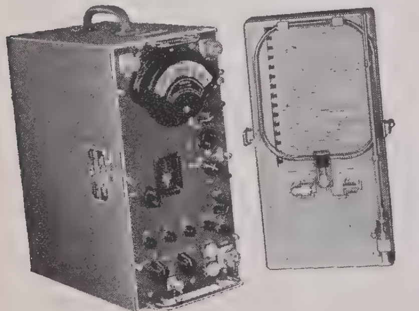
Commercial equivalent of TS-587/U.
Sensitivity as two-terminal voltmeter, (95 ohms balanced) 2 microvolts 15-125 MC; 5 microvolts 88-400 MC. Field intensity measurements using calibrated dipole. Frequency range includes FM and TV Bands.

VLF!

14 KC
to
250 KC

NM - 10A

Commercial equivalent of AN/URM-6.
A new achievement in sensitivity! Field intensity measurements, 1 microvolt-per-meter using rod; 10 microvolts-per-meter using shielded directive loop. As two-terminal voltmeter, 1 microvolt.



HF!

150 KC
to
25 MC

NM - 20A

Commercial equivalent of AN/PRM-1.
Self-contained batteries. A.C. supply optional. Sensitivity as two-terminal voltmeter, 1 microvolt. Field intensity with ½ meter rod antenna, 2 microvolts-per-meter; rotatable loop supplied. Includes standard broadcast band, radio range, WWV, and communications frequencies.

UHF!

375 MC
to
1000 MC

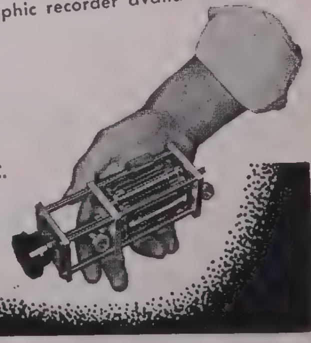
NM - 50A

Commercial equivalent of AN/URM-17.
Sensitivity as two-terminal voltmeter, (50-ohm coaxial input) 10 microvolts. Field intensity measurements using calibrated dipole. Frequency range includes Citizens Band and UHF color TV Band.

Since 1944 **Stoddart RI-FI*** instruments have established the standard for superior quality and unexcelled performance. These instruments fully comply with test equipment requirements of such radio interference specifications as JAN-I-225, ASA C63.2, 16E4(SHIPS), AN-I-24a, AN-I-42, AN-I-27a, AN-I-40 and others. Many of these specifications were written or revised to the standards of performance demonstrated in Stoddart equipment.

The **rugged** and **reliable** instruments illustrated above serve equally well in field or laboratory. Individually calibrated for consistent results using internal standard of reference. Meter scales marked in microvolts and DB above one microvolt. Function selector enables measurement of sinusoidal or complex waveforms, giving average, peak or quasi-peak values. Accessories provide means for measuring either conducted or radiated r.f. voltages. Graphic recorder available.

***Radio Interference and Field Intensity.**



Precision Attenuation for UHF!

Less than 1.2 VSWR to 3000 MC.
Turret Attenuator:
0, 10, 20, 30, 40, 50 DB.
Accuracy ± .5 DB.

Patents applied for.

STODDART AIRCRAFT RADIO CO.

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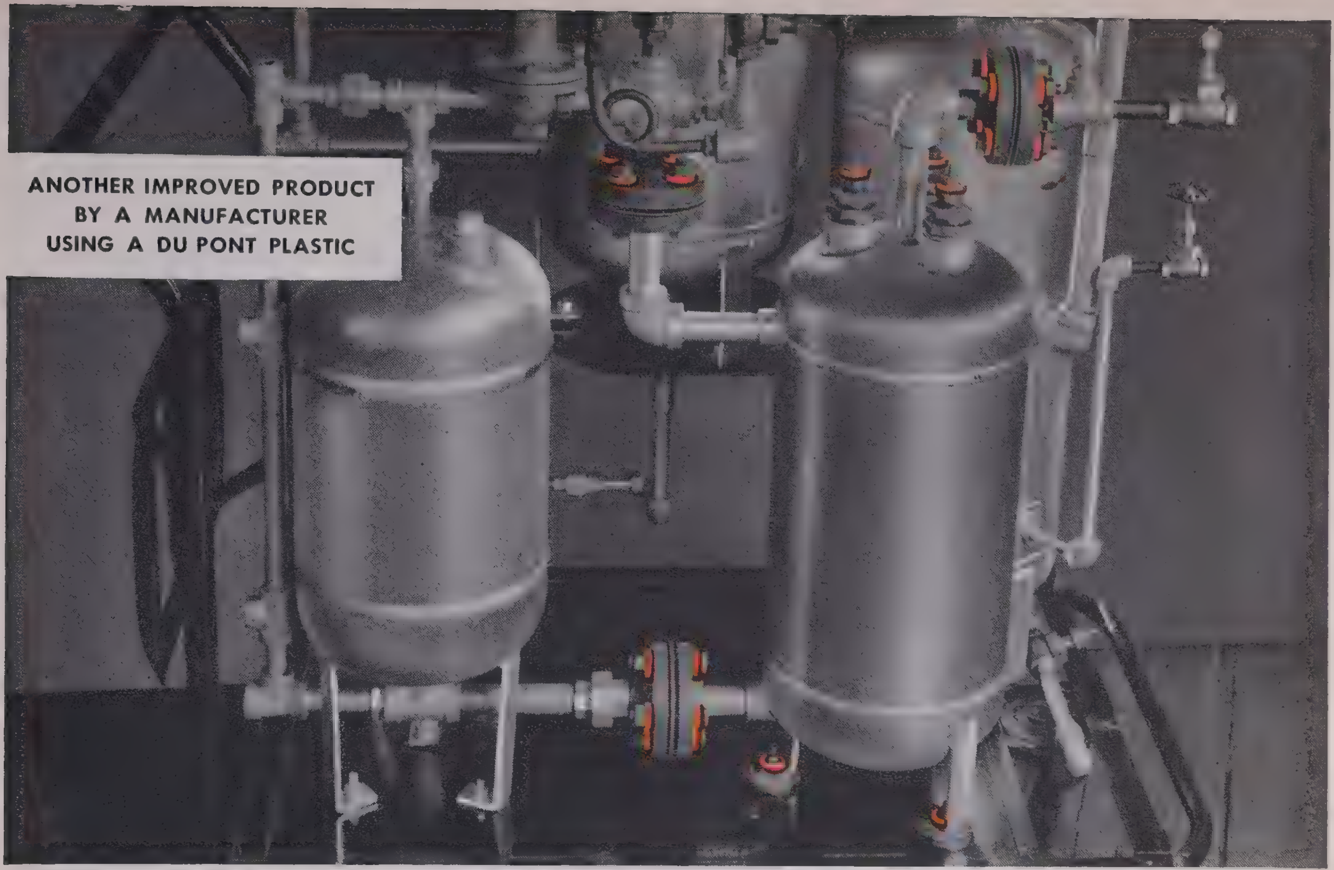
Hillside 9294

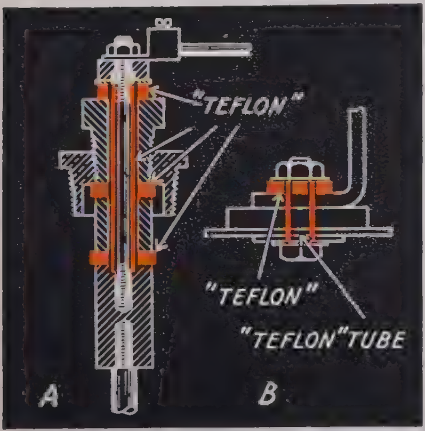


**ANOTHER IMPROVED PRODUCT
BY A MANUFACTURER
USING A DU PONT PLASTIC**

MOISTURE-PROOF "TEFLON"* AT DANGER-POINTS KEEPS STEAM FROM "SHORTING" GENERATOR

With high dielectric strength, heat-resistance, zero water-absorption, only Du Pont "Teflon" prevents electrical failures in portable steam generator

This manufacturer set out to design an electrically operated portable steam generator, for such uses as steam-jet cleaning, steam source for plastics-molding equipment, sterilizing of food equipment, and temporary steam source in industrial plants. A key problem was the prevention of electrical breakdowns under the unique conditions of the apparatus. It was necessary to (1) insulate electrodes going into the generator tank, and (2) isolate the generator tank from all other parts of the equipment. A material was needed that was completely moisture-proof, that would have high dielectric strength and provide a steam seal under high temperatures and pressures (up to 500 lb./sq. in.). Of all materials tested, only Du Pont "Teflon" tetrafluoroethylene resin succeeded.



(A) **"TEFLON"** in electrode housing provides high dielectric strength and high-temperature, high-pressure steam-seal.
(B) Insulation of "Teflon" on insulating flanges—one of key points where "Teflon" is used to insulate and isolate steam-generator tank from other parts.

"Teflon" was installed as electrode housings and gaskets, and at every point where the generator tank contacted regulator tanks or other parts. It provides high dielectric strength, zero water-absorption, heat resistance (up to 500°F.), and strength in compression. Thus a complete steam-seal is accomplished, and electrical failures are eliminated.

In addition, "Teflon" has outstanding electrical characteristics at high frequencies, and remarkable chemical inertness. Can your product use "Teflon"? It's supplied by Du Pont in standard shapes (rods, tubes, sheets and tape). Or we will recommend molders or fabricators who can supply finished parts of "Teflon." Write today for more information. Our technical staff will be glad to help you. E. I. du Pont de Nemours & Co. (Inc.), Polychemicals Dept., Plastics Sales Offices: 350 Fifth Ave., New York 1, N. Y.; 7 S. Dearborn St., Chicago 3, Ill.; 845 E. 60th St., Los Angeles, Calif.

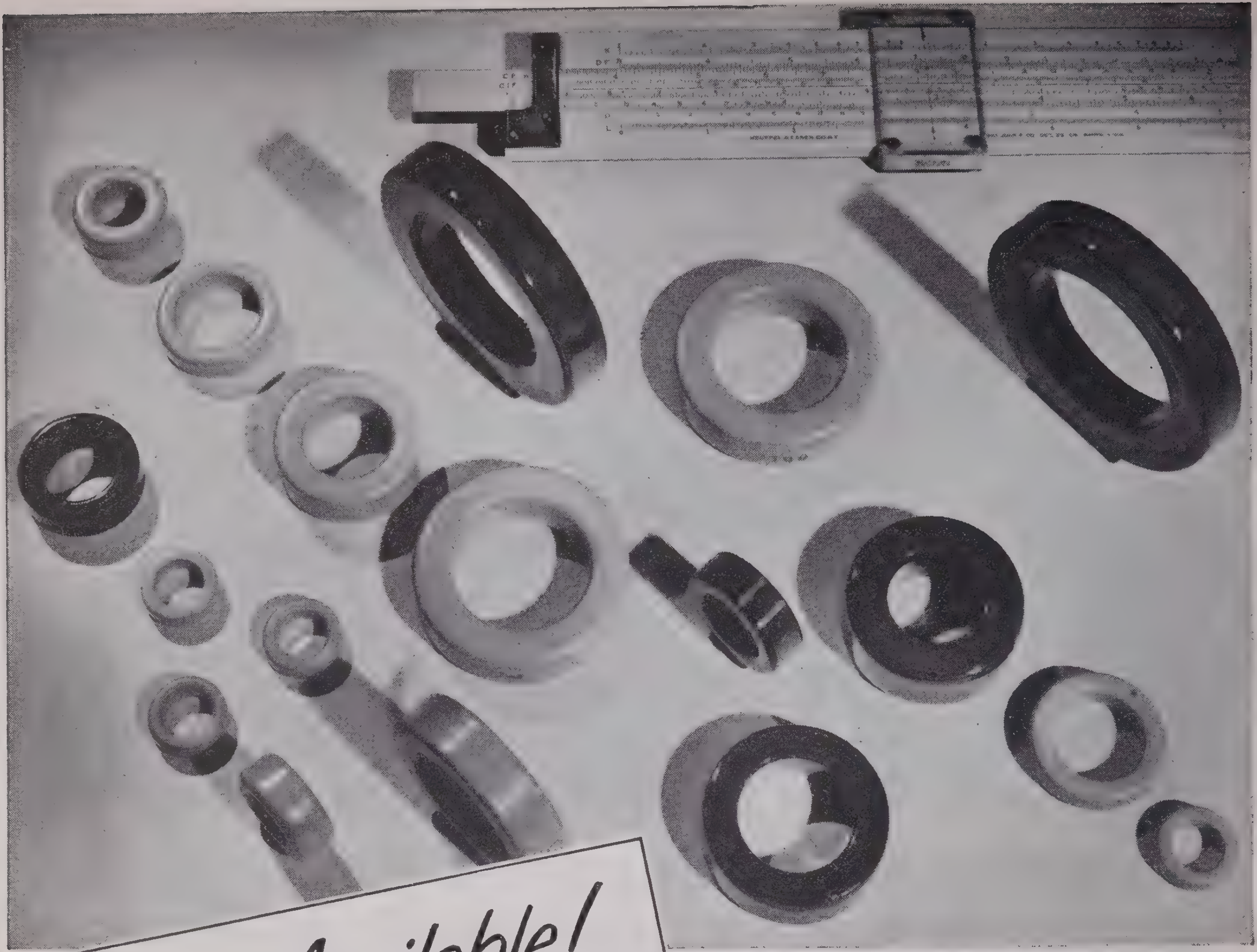
"Speedylectric" Portable Steam Generator manufactured by Livingstone Engineering Company, Worcester, Mass. Parts molded of "Teflon" by U. S. Gasket Company, Camden, N. J.

*REG. U. S. PAT. OFF.

DU PONT

Plastics

BETTER THINGS FOR BETTER LIVING
THROUGH CHEMISTRY



Now Available!

MOLYBDENUM PERMALLOY POWDER CORES*

HIGH Q TOROIDS for use in Loading Coils, Filters, Broadband Carrier Systems and Networks—for frequencies up to 200 K C

COMPLETE LINE OF CORES TO MEET YOUR NEEDS

★ Furnished in four standard permeabilities—125, 60, 26 and 14.

★ Available in a wide range of sizes to obtain nominal inductances as high as 281 mh/1000 turns.

★ These toroidal cores are given various types of enamel and varnish finishes, some of which permit winding with heavy Formex insulated wire without supplementary insulation over the core.

For high Q in a small volume, characterized by low eddy current and hysteresis losses, ARNOLD Moly Permalloy Powder Toroidal Cores are commercially available to meet high standards of physical and electrical requirements. They provide constant permeability over a wide range of flux density. The 125 Mu cores are recommended for use up to 15 kc, 60 Mu at 10 to 50 kc, 26 Mu at 30 to 75 kc, and 14 Mu at 50 to 200 kc. Many of these cores may be furnished stabilized to provide constant permeability (±0.1%) over a specific temperature range.

** Manufactured under licensing arrangements with Western Electric Company.*

W&D 2930

THE ARNOLD ENGINEERING COMPANY

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SUBSIDIARY OF ALLEGHENY LUDLUM STEEL CORPORATION
147 EAST ONTARIO STREET, CHICAGO 11, ILLINOIS

SAVE UP TO 25%...

with Rome Self-Supporting RoPrene Secondary and Service Drop Cable

TYPICAL ATTACHMENT TO SERVICE RISER
TYPICAL BUILT-IN ATTACHMENT
TYPICAL SERVICE TAP
TYPICAL SERVICE CONNECTION
TYPICAL DEAD-END ARRANGEMENT
TYPICAL POLE ANGLE OR CORNER HANGER

*TRADEMARK REGISTERED

Rated at 600 volts with maximum continuous copper temperature of 80° C.

Wherever overhead services are involved it will pay you to use Rome Self-Supporting Ro-Prene Secondary and Service Drop Cable. You can save up to 25% compared with the cost of conventional Service Drop Cable (Type SD). Construction is better and it lasts longer. There are no coverings to rot and festoon. It has remarkable weather resistance. It possesses excellent physical and electrical characteristics.

Installation and maintenance costs are also less than the cost of open weatherproof wire. Less labor and cheaper hardware can be used. When used as secondaries, Rome Self-Supporting Ro-Prene Cable is more compact, eliminates unsightly multiple wire construction, jointly occupied poles and long spans. On larger sizes, there is also a substantial saving in copper losses due to the lower reactance of a self-supporting cable compared with open wires.

NEW DATA AVAILABLE!—BULLETIN RS-4, just published contains specification and test details, as well as sag and tension data on Rome Self-Supporting Ro-Prene Cable. It's yours for the asking. Sign and mail the coupon below or write.

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ROME CABLE CORPORATION, Dept. EE-6, Rome, N. Y.
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ROME CABLE
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ROME · NEW YORK
From Bar to Finished Wire

HOLD LINE CONSTRUCTION COSTS TO A MINIMUM

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THESE ADVANCED DESIGN FEATURES:

1 Unrestricted expulsion chamber of QR arrester design eliminates "preferred current paths" which shorten conventional expulsion arrester life. Ring bus electrodes maintain correct gap calibration.

2 Trip-O-Link fuse cutout for positive fault clearance, simplicity and ease of re-fusing. Resilient spring mounting absorbs impact of heavy faults.

3 Direct-to-transformer mounting is simple and secure . . . lower installation costs. QRC with standard hanger for crossarm or direct pole mounting also available.

SPECIFY KEARNEY PRODUCTS

Install

The KEARNEY QRC

COMBINATION LIGHTNING ARRESTER and FUSE CUTOUT

Kearney **Combined Protection** for your conventional transformer is today's solution to the problem of getting the most out of your investment . . . providing more and better service with engineered economy. Initial cost is less, installation and maintenance costs are minimized . . . and your transformer is completely **protected.**

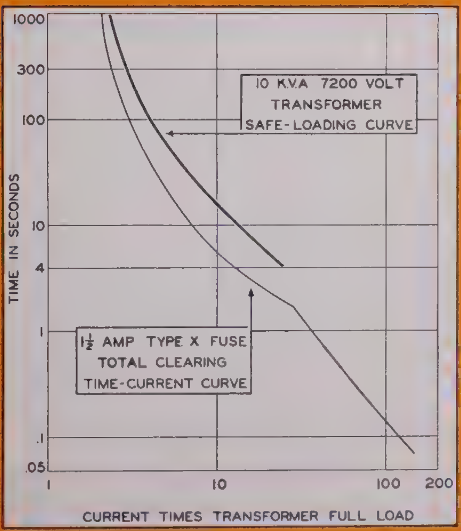
The QR arrester employed in Kearney QRC Combined Protection units provides low sparkover action for insulation security, high surge capacity for long life, and the unrestricted expulsion chamber construction assures quick, complete interruption of follow current.

The convenience and economy of the Trip-O-Link fuse cutout is your further assurance of complete protection with maximum economy.

FOR TRANSFORMER PROTECTION

The KEARNEY Type X FUSE LINK

Gives You OVERLOAD PROTECTION plus HIGH SURGE CAPACITY



Protection of service continuity is an added advantage of the QRC when you fuse with the Type X link. Compare the time-current curve of the 1½ ampere Type X fuse (X) with the safe loading curve (A) of a 10 KVA, 7200 volt transformer. The extra protection gained for long duration overcurrents is accomplished at no sacrifice of surge capacity . . . assurance against unnecessary outages due to switching surges and other non-damaging transients.

Write for complete information on the QRC, characteristics of the QR arrester and the Type X fuse link.

JAMES R. KEARNEY CORPORATION
4224-42 Clayton Avenue St. Louis 10, Missouri
Canadian Plant: Guelph, Ontario

JAMES R.
KEARNEY
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ST. LOUIS, MO.

Better Construction—SAFER Maintenance

DU MONT OSCILLOGRAPHY *for* SURGE TESTING

. . . by combining the versatility of the sealed-off cathode-ray tube.

. . . and convenient photographic recording.

. . . with the precision of a Du Mont High-voltage Cathode-ray Oscillograph

Simplified

TYPE 293

Operating a Du Mont High-voltage Cathode-ray Tube to meet requirements of surge-test recording, and equipped with a detachable 35-mm camera using an f/1.5 coated lens, the Du Mont Type 293 Cathode-ray Oscillograph quickly provides an accurate recording of an impulse applied for testing power equipment and other products designed to withstand uncontrollable surges of excessive amplitudes.

An illuminated data card and color-selective mirror permit simultaneous viewing and recording of waveforms appearing on the cathode-ray screen.

Type 293 is a complete surge-test oscillograph packaged in a mobile, simple-to-operate unit. Incorporates semi-logarithmic driven sweeps, vertical-signal delay, crystal-controlled time calibration of horizontal deflection, and metered voltage calibration of vertical deflection, to obtain a highly accurate qualitative and quantitative analysis of a test surge.

CATHODE-RAY TUBE: Type K1068 (Du Mont Type 5RP11A modified with metal-backed screen and inter-electrode shield).

INPUT-SIGNAL ATTENUATION: Ten-step, in equal increments of 10%, accurate within ±1% of unattenuated value.

MAXIMUM INPUT SIGNAL: 2500 volts peak, maximum pulse duration of 1000 microseconds; maximum repetition rate, 30 pulses per minute.

FREQUENCY RESPONSE OF Y-AXIS: Essentially uniform from d-c to 25 megacycles.

TRANSIENT RESPONSE: No appreciable distortion of rise time of 0.01 microsecond.

VERTICAL-SIGNAL DELAY: 0.25 microsecond.

SEMI-LOGARITHMIC SWEEP DURATIONS: 0.5, 2.5, 10, 50, 250 and 1000 microseconds.

METERED VOLTAGE CALIBRATION: Continuously variable d-c potential; accuracy, 1% of full scale.

TIMING-MARKER INTERVALS: 0.05, 0.1, 1, 10, 100 microseconds; accuracy, 0.01%.

SWEEP INITIATION: External from signal, manual by push-button, internal from signal, or internal from 60 cycles.

TRIGGER OUTPUT: 1200 volts; repetition rate up to 30 pulses per minute, manually initiated.

DU MONT *for Oscillography*

ALLEN B. DU MONT LABORATORIES, INC. • INSTRUMENT DIVISION • CLIFTON, N. J.

SYMPOSIUM on ELECTRICAL PROPERTIES of SEMICONDUCTORS and the TRANSISTOR

A series of four articles, compilations of papers originally presented at a symposium on electrical properties of semiconductors and the transistor, held during the AIEE Summer General Meeting, Swampscott, Mass., June 1949. Sponsored by the Subcommittee on Electrical Properties of Solids and Liquids of the AIEE Committee on Basic Sciences.

It is hoped that this pamphlet (S-36, January 1950) will prove useful not only to the practicing engineer and teacher, but also to engineering students as an introduction to this field of electrical engineering.

Price is $0.50 ($0.25 to AIEE members). Send orders to: Order Department, AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS, 33 West 39th Street, New York 18, N. Y.

6-50

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A refund is offered for the 1942, 1947, and 1948 bound volumes of AIEE TRANSACTIONS. Please mail (parcel post) to the American Institute of Electrical Engineers, 33 West 39th Street, New York 18, N. Y., printing your name and address upon the wrapper. $4.00 plus postage, will be paid for each volume, provided the books are in a saleable condition.

6-50

HOLOPHANE Lights Both Houses of Congress

HOLOPHANE Lighting in the newly modernized Chamber of the United States Senate.

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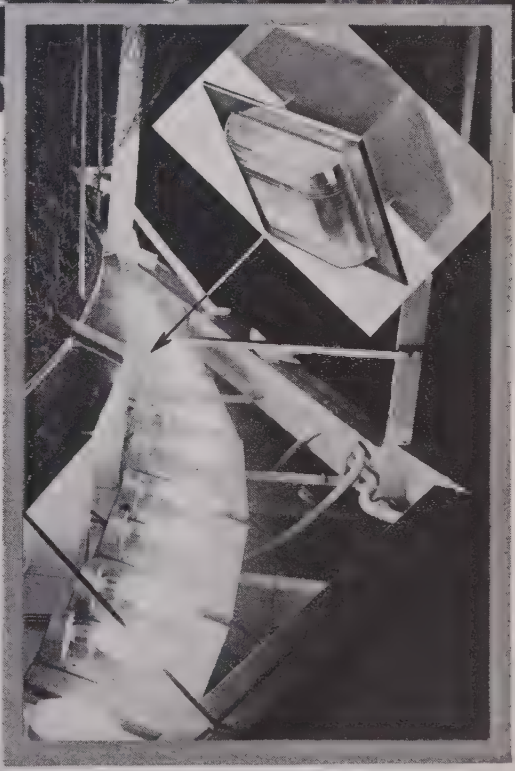
THOMAS W. MARSHALL & JAMES M. GONGWER, *Consulting Engineers*
HARBESON, HOUGH, LIVINGSTON & LARSON, *Consultants*
LEO H. CLEARY, *Electrical Engineer*

In the reconstruction and remodeling of both Houses of Congress, HOLOPHANE units were selected. The specialized knowledge and long-time experience of HOLOPHANE engineers were called upon once again to integrate the lighting with the needs of an important interior.

HOLOPHANE *Engineering Service, for which there is no charge, stands ready to help you with your needs.*



CONTROLENS* installation around cove—units open for relamping.

Holophane
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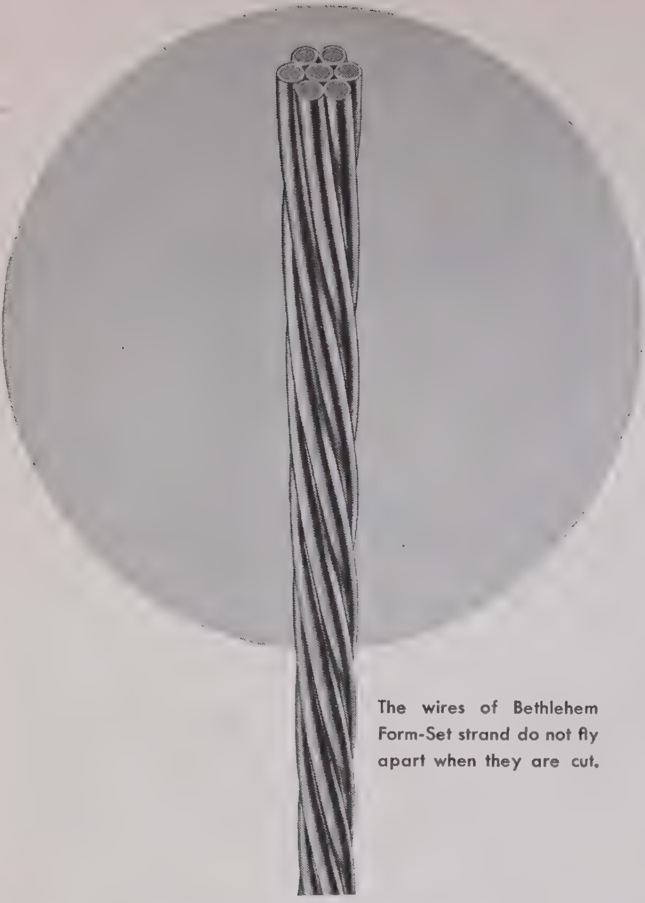
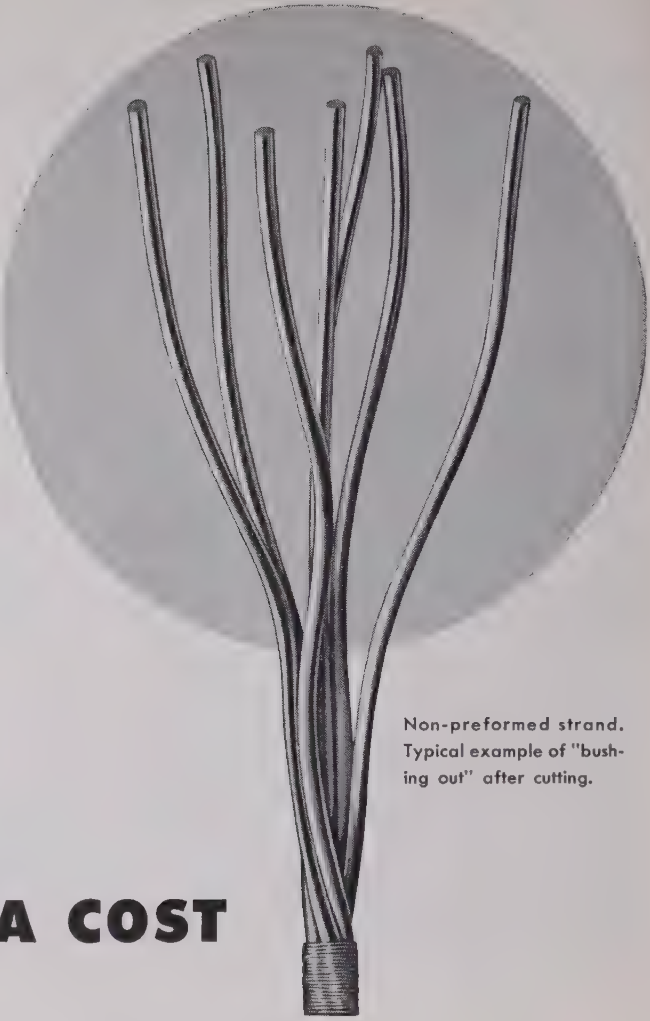
Lighting Authorities Since 1898 • 342 MADISON AVENUE, NEW YORK 17, N.Y.
THE HOLOPHANE COMPANY, LTD., THE QUEENSWAY, TORONTO 14, ONTARIO

*Reg. U. S. Pat. Off.



The wires of Bethlehem Form-Set strand do not fly apart when they are cut.



Non-preformed strand. Typical example of "bushing out" after cutting.

SO **MUCH** EXTRA FOR SO **LITTLE** EXTRA COST

That's one very good definition of Bethlehem's Form-Set strand. Form-Set is preformed and therefore has several advantages over the non-preformed type—yet you pay virtually no more for it. The slight additional charge is far more than offset by the extra values you get.

Form-Set is "gentle"; it has no inner tension. Preforming curbs wildness. Note, in the photographs, the difference between the Form-Set strand and the non-preformed sample. Both pieces have been cut; yet even without seizing, the wires of the Form-Set strand lie snugly in place. No bushing, no spraying in every direction.

This characteristic makes Form-Set easier to handle . . . easier to insert in fittings. Saves time, results in better work. The preformed construction is particularly helpful in the high-strength and extra-high-strength grades.

Widespread use in the field has proved these statements many times over. You yourself might like to know more about Form-Set; if so, ask a Bethlehem man to call. He'll tell you the full story.

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation

Export Distributor: Bethlehem Steel Export Corporation

BETHLEHEM STEEL

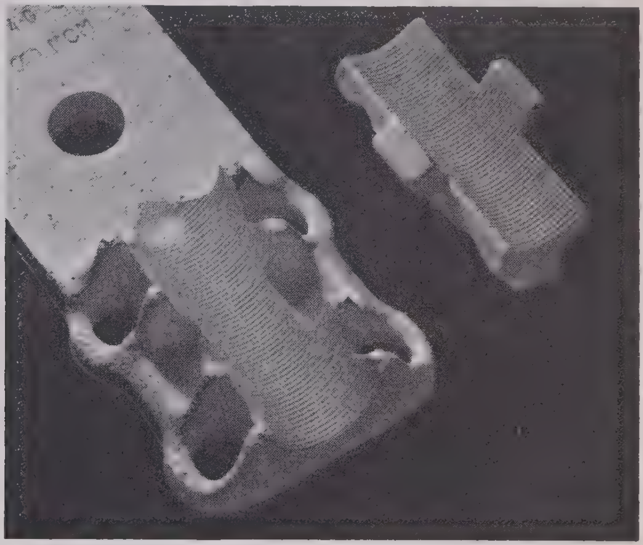
Bethlehem *FORM-SET* Strand

GENERAL ELECTRIC POWER CONNECTORS HAVE

MACHINE-SERRATED CONTACT SURFACES

for high pull-out strength

for low contact losses



Here's the way the machine-serrated contact surfaces on G-E power connectors bite into the conductor (500 MCM tubing shown). For this test a hand wrench was used to tighten the connector (right). Tension was then applied. Above photo shows that the copper "backed up." This action assures a high-conductivity joint that will resist vibration and give positive pressure on the conductor at all times.

Disassembled G-E power connector showing the sharp serrations machined (not merely cast) into the contact surfaces—an exclusive General Electric feature. Note that all contact surfaces are silvered, another standard feature on all G-E connectors. The photo also shows the interlocking sides that confine cable strands within the conductor enclosure thus obtaining full advantage of the cable's current-carrying capacity.

Place an order today with your G-E sales representative and start realizing the many benefits to be gained by using General Electric connectors. Also, write for a copy of bulletin GEC-400 that contains 40 pages of valuable information on G-E connectors and see for yourself how easy they are to order. Write to *Apparatus Department, Section 856-54, General Electric Company, Schenectady 5, New York.*

GENERAL ELECTRIC

856-54

TO MEET TODAY'S AND TOMORROW'S HIGHER DISTRIBUTION VOLTAGE NEEDS

PINCO L1510's...

RIGHT for the Job...RIGHT on the Job!

More and more companies are using Pinco L 1510's for dead-ending on their distribution lines because of their unusual strength-for-size characteristics. Incorporating design features which have enabled them to roll up millions of service years without replacements for electrical or mechanical failure, these rugged L 1510's have proved conclusively that maintenance costs *stay down* when Pinco goes up! So specify Pinco and Pinco performance will prove the wisdom of your choice.

See page 64, Pinco Catalog No. 49 for complete electrical and mechanical characteristics.

The Porcelain Insulator Corporation
763 Main Street, Lima, N. Y.

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American Standard LETTER SYMBOLS for ELECTRICAL QUANTITIES

This American Standard (Z10.5 — June 1949), which has been prepared by a subcommittee of the Sectional Committee on Letter Symbols and Abbreviations for Science and Engineering, is a revision of ASA Z10g1 and AIEE 17g1.

General principles of letter symbol standardization, a typographical notation for distinguishing, in the equations of the printed page, between the symbols for scalar, complex (phasor), and vector quantities are given, as well as tabulations of the symbols in alphabetical order of the names of quantities, English letter symbols, and Greek letter symbols.

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For the best . . . "Call Cleveland." Samples on request.

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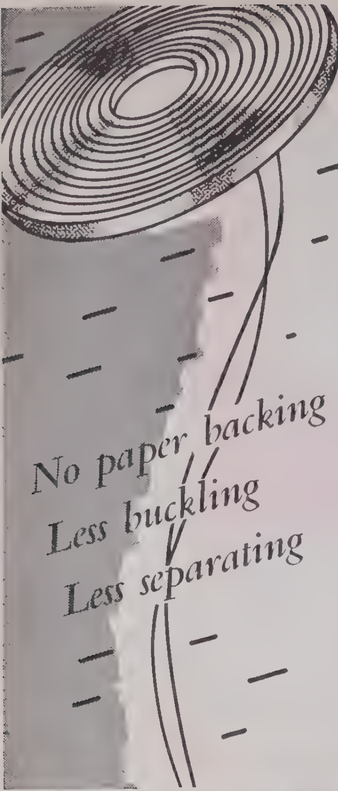

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INSULATING TAPE

If you've had trouble applying insulating tapes of the usual construction—mica sandwiched between glass cloth and paper, and of the usual thickness, .005" or more—just try *this* tape.

On turns of small radius it doesn't buckle nearly as much, because it's backed one side only. Its premium mica is hand laid and bonded so completely to the glass cloth it holds tight — runs through winding machines like a dream.

Supplied with a silicone varnish for extra-high temperatures, standard varnish for the usual Class B use. Available with single layer of mica in .0035" thickness, double layer mica, .005"; both thicknesses are made in widths of half, three-quarter and one inch.

Send for a sample. Inspect it. Try it. It's the answer to a lot of problems. And don't forget—whatever your electrical insulation needs, National has it, ready for quick shipment—and it's *good.*

NATIONAL ELECTRIC COIL COMPANY
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ELECTRICAL ENGINEERS: MAKERS OF ELECTRICAL COILS AND INSULATION— REDESIGNING AND REPAIRING OF ROTATING ELECTRICAL MACHINES
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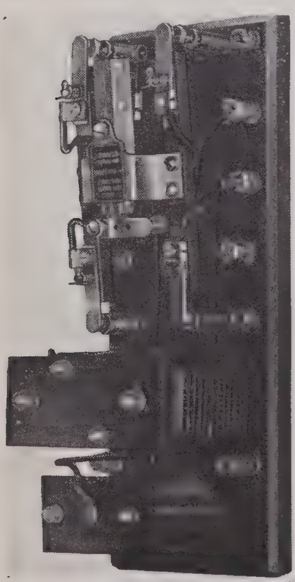

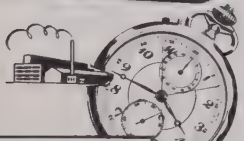

Another Important Development in the Series of → ASCO Electro-Magnetic CONTROLS

POWER RELAY with BUILT-IN DELAY FEATURE

. . . factory set from ½ to 3 seconds

Again we announce an important development in the long line of ASCO Electromagnetic controls . . . this time a Fixed Delay Relay for use with Automatic Transfer Switches. With this Relay, you can set a Transfer Switch so that it will not throw on transient outage until a predetermined period—½ to 3 seconds—is passed. This avoids switch operation when power loss is only momentary.

It's a magnetically held Relay without dash pot, motors, or moving parts in the time element. Its unique built-in fixed time delay arrangement disengages on any selected value between ½ and 3 seconds. It has utility power construction and is rated at 25 amperes with single or double throw. It's the Relay now used on many ASCO Transfer Switches to guard against momentary outage due to transient conditions.

Possibly this is the very Time Delay Relay (Bulletin 1054-188S) you have been looking for. Write us about your requirements and let's see.

We also manufacture a complete line of Solenoid Operated Valves for Automatic and Remote Control of Liquids and Gases

Automatic Switch Co.
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AUTOMATIC TRANSFER SWITCHES • REMOTE CONTROL SWITCHES • CONTACTORS • RELAYS

(*Continued from page 22A*)

projector can be used with existing image orthicon equipment, the addition of the projector can double the present film capacity of operating stations. The other purpose of the Superspeed projector is its use as a background projector for studio production. Moving scenery can be projected upon a translucent screen behind the actors to add the lifelike touch to storm scenes and landscapes, and so forth. The projector is offered in two models: the universal model, mounted on a movable pedestal, equipped with a 100-watt lamp for direct projection to image orthicon equipment, and a 1,000-watt lamp for rear screen projection. The heavy duty model is pedestal-mounted and equipped with an arc light and 1,000-watt projection lamp for rear-screen projection up to 12 feet by 15 feet. Additional information may be obtained from the Allen B. Du Mont Laboratories.

A-C Resistance Boxes. New resistance boxes just announced by Leeds and Northrup Company are designed for use as moderate-precision adjustable standards for d-c and a-c resistance measurements up to medium frequencies. Principal feature of the boxes is a new type of rotary switch having very low and stable contact resistance, obtained through the use of solid silver switch contacts and silver alloy multiple-leaf brushes. Zero or contact resistance is less than 0.002 ohm per decade and changes less than 0.0005 ohm per decade on accelerated life tests. Limit of error is plus or minus (0.05 per cent + 0.005 ohm). Four-dial models have a range of 11,110 ohms in 1-ohm steps; 5-dial models cover 11,111 ohms in 0.1-ohm steps or 111,110 ohms in 1-ohm steps. Time constant at 50 kc for usual range of dial settings is less than 0.05 microsecond. Further information on the resistance boxes is available from the Leeds and Northrup Company, 4934 Stenton Avenue, Philadelphia 44, Pa.

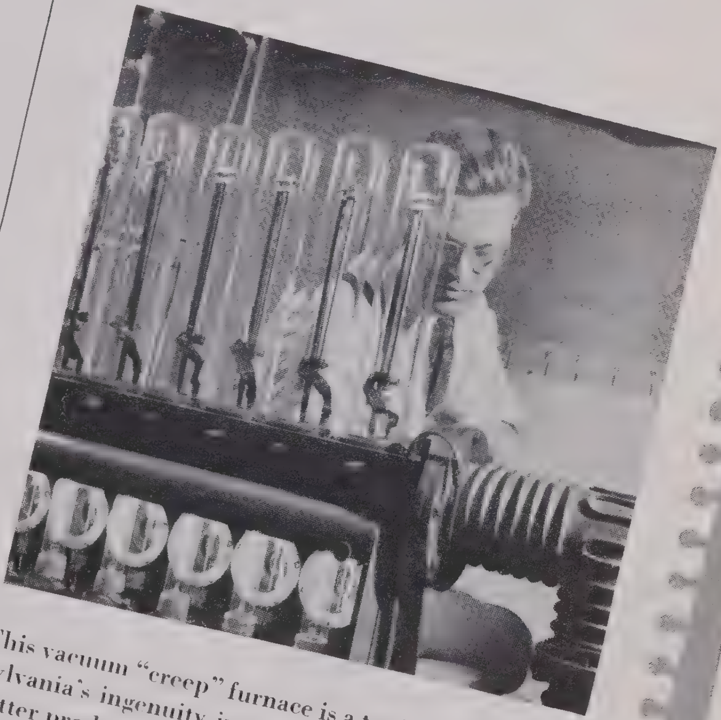
Allis-Chalmers Developments. The Allis-Chalmers Company has announced moderate capacity oil circuit breakers of quick-clearing, non-oil-throwing design for outdoor distribution service where safe operation is required without frequent adjustment or inspection. Designated types *OZ-110* and *OZ-210*, the circuit breakers have a rated voltage of 23.0 kv or less up to 250,000 kva interrupting capacity. They can be supplied for automatic reclosing duty, and are fully described in bulletin *71B6093C*. Another Allis-Chalmers development is the new transformer-type *AFR* 5/8-per cent step feeder voltage regulators which are available in ratings recommended by the joint Edison Electric Institute and National Electrical Manufacturers Association committee on preferred voltage ratings. To meet many different installation requirements, the regulator has interchangeable source and load bushing leads. A new bushing arrangement affords greater electrical clearance between phases. By-pass arrestors and bushing line terminals that can be lined up to give symmetrical configuration

(*Continued on page 40A*)

A page from the note-book of Sylvania Research

Better Tubes through Research in filamentary wire

SYLVANIA'S continuous research means better electronic tubes. For example, with the special research tool shown at the right the minute stretch or "creep" of filament wires is studied under the same conditions of temperature, vacuum and pressure found in electronic tubes. Using this instrument, Sylvania engineers have uncovered many new facts about filamentary alloys. From studies such as this Sylvania is able to give you better tubes of longer life and higher quality.



This vacuum "creep" furnace is a typical example of Sylvania's ingenuity in research for better and still better products.

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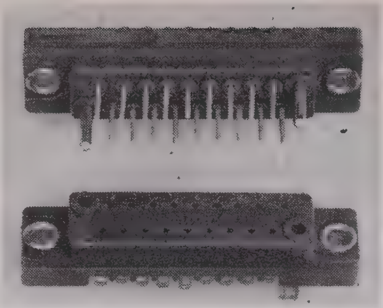
. . . standard components on fine electrical and electronic equipment. After *33 years* of building electrical specialties, Cannon Electric continues to pioneer new and better types of connectors, maintaining its reputation for progress and development. In the 13 *major type series* of connectors will be found most of the requirements for quick disconnection of electrical circuits. For a survey of the general line, write for *Condensed Catalog.*



DPM—RACK AND PANEL TYPE CONNECTORS

. . . for narrow mounting requirements, this design follows the general construction of other Cannon Electric DP Connectors and is available in two sizes and contact arrangements: 14 and 20.

The two large polarizing contacts are 10-amp., 120-volt; small contacts 5-amp., 120-volt. Insulation is melamine, contacts are brass, silver plated on pins, cadmium plated on socket contacts.

Address Dept. F-311 for further information. Cannon Electric Development Company, Division of Cannon Manufacturing Corporation, 3209 Humboldt St., Los Angeles 31, Calif. Canadian factory and offices, Toronto, Ontario. World export (excepting British Empire) Frazar & Hansen, San Francisco, Los Angeles and New York.

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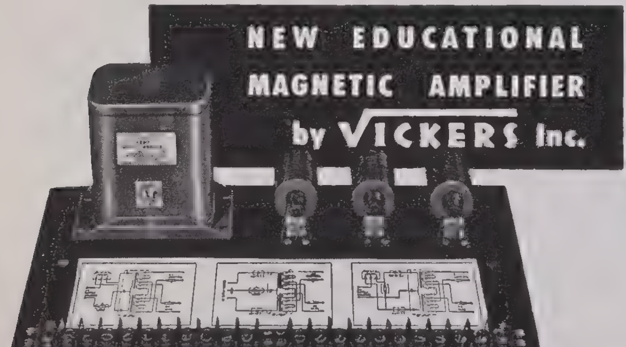

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The report covers the basic features of electrical wiring applicable to all types of commercial buildings. It will serve as a guide to the young engineer when first he undertakes work of this character to help him avoid serious omissions and mistakes. This is not an AIEE Standard, and the recommendations are not intended to be mandatory or restrictive.

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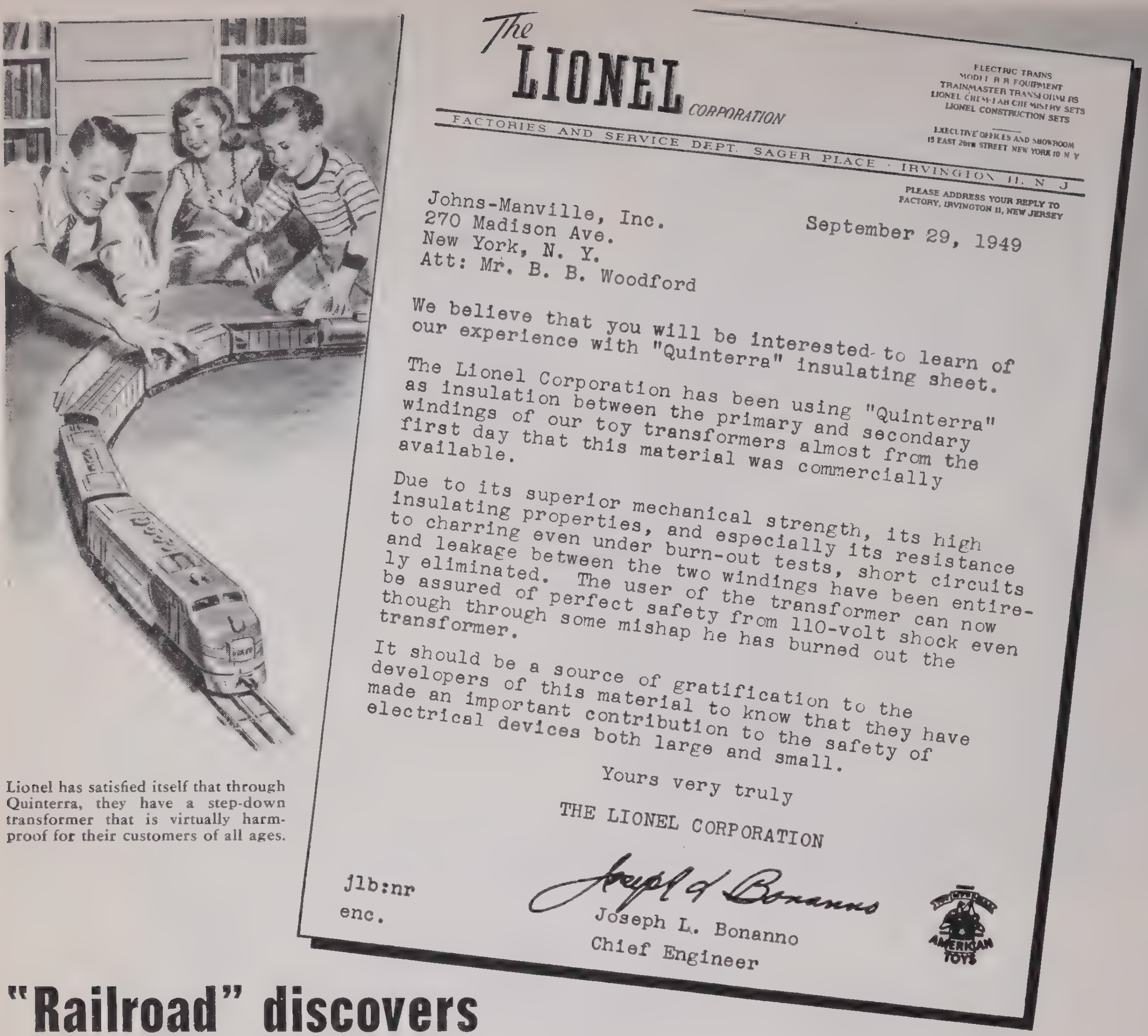

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September 29, 1949

Johns-Manville, Inc.
270 Madison Ave.
New York, N. Y.
Att: Mr. B. B. Woodford

We believe that you will be interested to learn of our experience with "Quinterra" insulating sheet.

The Lionel Corporation has been using "Quinterra" as insulation between the primary and secondary windings of our toy transformers almost from the first day that this material was commercially available.

Due to its superior mechanical strength, its high insulating properties, and especially its resistance to charring even under burn-out tests, short circuits and leakage between the two windings have been entirely eliminated. The user of the transformer can now be assured of perfect safety from 110-volt shock even though through some mishap he has burned out the transformer.

It should be a source of gratification to the developers of this material to know that they have made an important contribution to the safety of electrical devices both large and small.

Yours very truly

THE LIONEL CORPORATION

Joseph L. Bonanno

Joseph L. Bonanno
Chief Engineer

jlb:nr
enc.

AMERICAN TOYS

Lionel has satisfied itself that through Quinterra, they have a step-down transformer that is virtually harmproof for their customers of all ages.

"Railroad" discovers *Quinterra* insulation adds new safety factor for customers

Report after report from users of Quinterra shows that this revolutionary, new Johns-Manville purified asbestos high-temperature electrical insulation is effecting major improvements in transformer design.

And more than that. These reports show that manufacturers are not only obtaining important sales advantages for their electrical products through the use of Quinterra . . . but they are also saving time and money in their manufacturing operations, as well!

This paper-thin, continuous sheet insulation is being widely used in transformers and coils. Its lasting dielectric strength, due to its resistance to pyrolysis, assures a greater safety factor and longer operating life. Quinterra withstands substantially higher temperatures than the hot-spot limit of 130C for Class B insulations.

QUINTERRA

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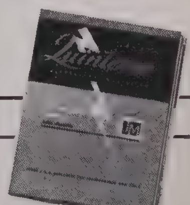

Johns-Manville
ELECTRICAL INSULATIONS

Johns-Manville
Box 290, New York 16, N. Y.

Kindly send me a copy of
Johns-Manville Quinterra Electrical Insulation EL-34A.

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To: MOLONEY ELECTRIC COMPANY

Installed in a large western substation, these four Moloney autotransformers are each rated at 15,000 kva, and step down the transmission voltage of 112,500 to 60,000. Each has a tertiary winding of 6,667-kva capacity at 10,500 volts for operation of a synchronous condenser. The inert gas pressure system for oil preservation contains three-stage pressure regulating equipment. Tanks are designed to withstand full vacuum without oil. And like many other Moloney transformers, these are equipped with . . .

BUSHINGS ONE OF THE FINEST COMPONENTS OF *ANY* TRANSFORMER . . . .

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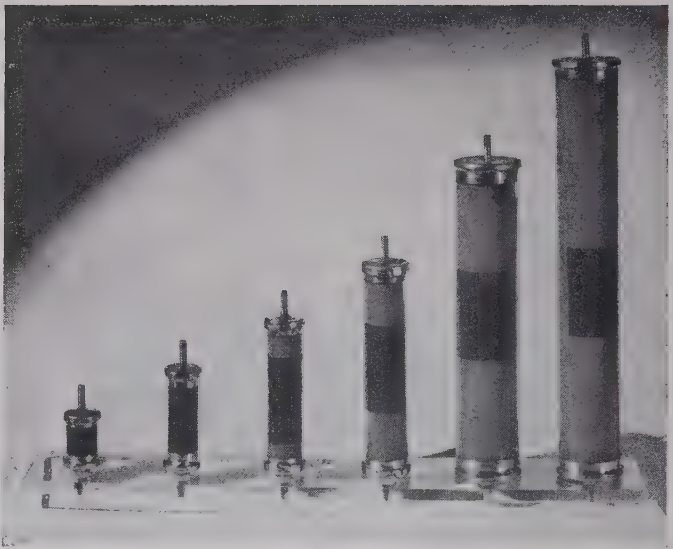

PROBLEM: To design a 1000 mmf. capacitor rated 25000 V at 12 amperes from 500 to 1700 kilocycles. To cost less than a mica capacitor. To occupy less chassis space and less total volume without loss of efficiency or reliability.

SOLUTION: Plasticon Type LS Capacitors rated at 3500 Volts have been available for three years. Using similar design factors, a 1000 mmf-25 KV Glassmike was constructed. Tests under full power showed a Q of 3000 at 1 megacycle. The temperature rise was 15°C at 12 amps. at 500 Kc. This capacitor, LSG102-25, was substituted for a JAN-C-5,CM90 style Mica capacitor in a Commercial Broadcast Transmitter. The LSG102-25 Plasticons have been in operation since last June. The Plasticons are approximately 40% of the cost of the mica capacitors. The base dimension of the mica capacitor is 5" x 6½"; the height is 5¾". The Plasticon LSG102-25 is 1⅜" OD x 8" long.

In the near future a complete line of high voltage–high power Plasticon LSGs will be announced. We are now filling orders for LSGs in the following ranges: 3,500V, 7,000V, 10,500V, 14,000V, 17,000V, 20,000V and 25,000V. Sizes range from 19/32" to 1⅜" O.D. and from 1" to 8" in length. The current ratings do not duplicate mica capacitors. In general more parallel and fewer series units are required. Plasticon LSGs are more compact, easier to mount and less expensive.

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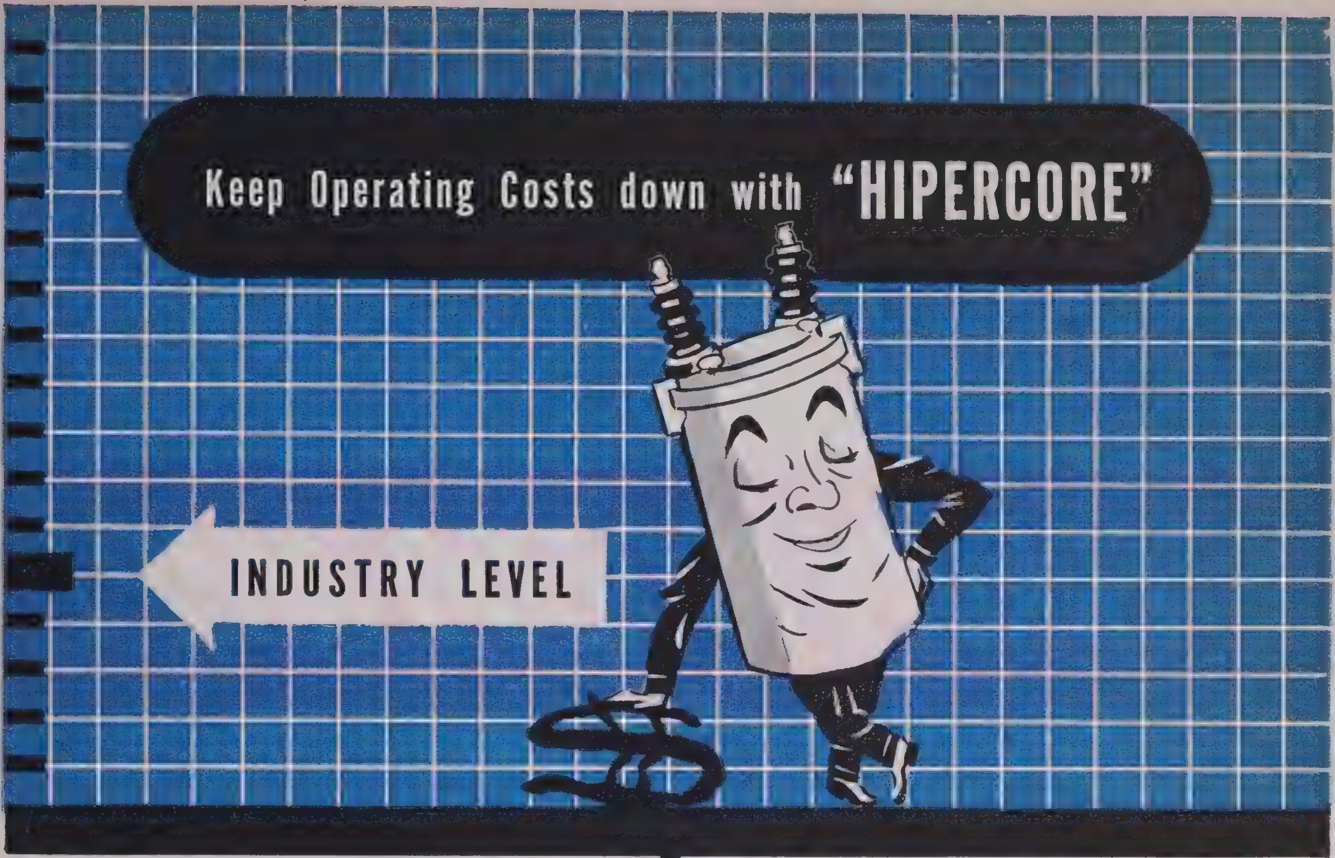


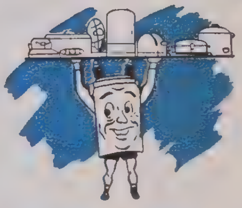
Keep operating costs down by reducing transformer outages. Savings obtained by economical system planning and efficient operation can be wiped out quickly by a higher-than-average transformer mortality rate.

It takes more than high electrical efficiency or low exciting current, or low impedance to make a transformer economical. It takes built-in ruggedness with ability to withstand severe overloads, lightning surges and intermittent secondary faults. It takes *balanced design* . . . no one feature exploited at the expense of another. The chain is no stronger than its weakest link.

For low overall cost over a period of years, specify Moloney HiperCore Distribution Transformers.

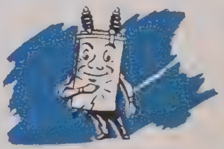
Improved Short-Time Overload Capacity

Improved short-time overload characteristics provide better peak load performance and longer life. Reduced coil mass, achieved through use of oriented steel cores together with the extensive use of cooling ducts, results in more rapid cooling of windings and lower hottest-spot temperature gradient.



High Surge Resistance

Moloney HiperCore Transformers are designed to withstand lightning surges well in excess of the minimum requirements. A high factor of safety in properly distributed insulation and vacuum processing produce the ultimate in overall dielectric strength.



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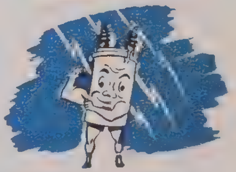
Coils are made mechanically rigid through the use of heat curing bonding material. The coils are blocked solidly by the impregnated core which is in turn banded with tons of force, providing maximum strength against short circuit forces.



- LONGER OPERATING LIFE
- HIGH FACTOR-OF-SAFETY IN DESIGN
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Bulletin needed for: ......Reference purposes ......Planning immediate project

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These new General Electric Type EJ-6 current-limiting power fuses are for application on 600-volt a-c (and below) circuits where the short-circuit current may reach 100,000 amperes. You get increased protection when you use EJ-6 fuses.

RATINGS Standard NECS size fuses are available in 30, 60, 100 and 200 ampere sizes in both 250- and 600-volt ratings. All ferrules and blades have silver surfaces to reduce contact losses. Fuses will interrupt 100,000 rms amperes total asymmetrical current including the d-c component of fault current.

FUSE CLIPS The new EJ-6 fuses are designed to fit standard NECS fuse clips. Also available are special-design clips that prevent the insertion of other NECS fuses. Short-circuit stresses cannot jar fuses loose from these clips. Protect your equipment and personnel by allowing only fuses of high interrupting capacity to guard your circuits.

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GENERAL ELECTRIC

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BIDDLE
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NUMBER 1 OF A SERIES

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A *NEW* CONSTANT-VOLTAGE TYPE MEGGER® INSULATION TESTER IN LOW-PRICED RANGE

The trim, modern design of this newcomer to the Megger family of insulation resistance testing instruments is only part of the story. Ohm scale and selector switch are available on all instruments in ranges of 0 to 10 megohms, 100 volts d-c; 0 to 20 megohms, 250 volts d-c; 0 to 50 megohms, 500 volts d-c. The constant-voltage feature is standard with all of these new CVM (Constant Voltage Type Megger) Insulation Testers. These features plus several other mechanical refinements contribute to make this instrument a worthy addition to the popular line of Megger Instruments.

Bulletin 21-80-EE, describing this instrument, will be sent on request. Check the coupon below.

NEW BIDDLE IMPULSE CABLE FAULT LOCATOR

Demonstrated by Applications Engineer on 7,000-Mile Tour

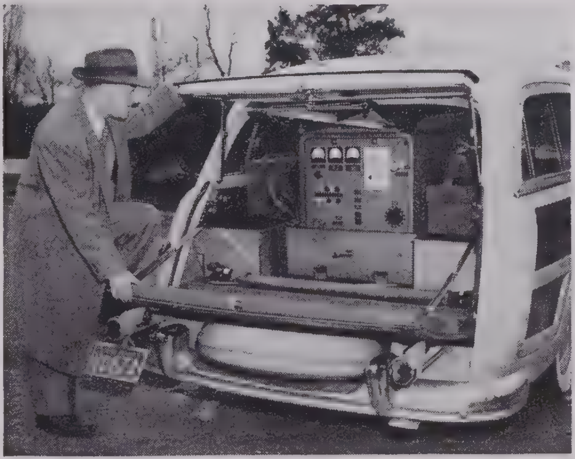

Photo shows Ed Curdts, James G. Biddle Company's Applications Engineer checking the installation of the new Biddle Impulse Cable Fault Locator in the company's new demonstration station wagon. Mr. Curdts spoke in Houston, Texas, before the Petroleum Industry Electrical Association on "Grounding Principles and Practices as Applied to Industrial Plants." This was the first leg of his projected 7,000-mile tour throughout the U. S., demonstrating Biddle equipment to industrial and power companies.

The Biddle Impulse Cable Fault Locator is a new device for locating faults on electric power cable. The apparatus is of the tracer current type. It consists of a high-voltage impulse transmitter and a specially designed detector. Equipment is readily transportable. Operates merely by plugging into any a-c lighting current.

Bulletin 65-EE, mailed to you on request, describes and illustrates the equipment.

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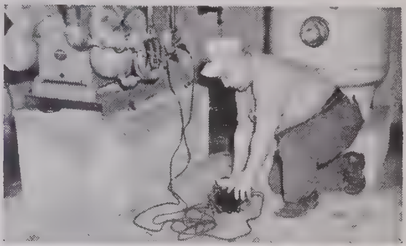
Large Chemical Company Finds "Megger" Insulation Testing is "Good Insurance"



One of the largest chemical companies in the world with over 45 plants is regularly testing motors, generators, cables and other electrical equipment. Megger Insulation Testers are standard equipment in every one of their plants.

Safety is a very vital consideration in the chemical industry. Years of careful recording of tests have proved to this company that regular systematic insulation resistance measurements represent extremely low cost insurance against fire, explosion and loss of life that are hazards of electrical failure.

Insurance Inspectors urge the systematic use of Megger Insulation Resistance Testers in all industries. A "Megger" instrument is a relatively small investment for the peace of mind it gives you and the greater efficiency it gives your plant maintenance crew.

Write or check coupon below for Bulletin 21-P-8-EE. This little booklet covers insulation resistance testing in simple language; packed with electrical maintenance hints.

Is Your LITERATURE FILE *Up to Date?*

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Aged in an air oven for sixteen weeks at the grueling temperature of 250 F. (121 C.) Anhydrex XX remained rubber-like in quality and appearance, was still suitable for continued use. It retained approximately half of its tensile strength, nearly two-thirds its elongation. Most important of all, its rate of deterioration after the first few weeks was very slight, indicating exceptional stability and long life.

Ordinary oil base and heat-resistant compounds could not match this performance. Inside of only three weeks both had become brittle and, upon bending, immediately cracked and crumbled.

Aged at the same high temperature for seven days, Anhydrex XX was immersed for a week in distilled water at 158 F. (70 C.). It would not absorb more than 15 mg. per square inch of exposed surface. Bent around a mandrel, it was exposed to .03% ozone for four hours yet would not crack.

Anhydrex XX is the only insulation that provides this valuable combination. So that you may determine fully the effectiveness and stability of these properties even after years of service, we have drawn up an ironclad specification for Anhydrex XX which we will gladly send you upon request. Simply fill in and mail the coupon below.

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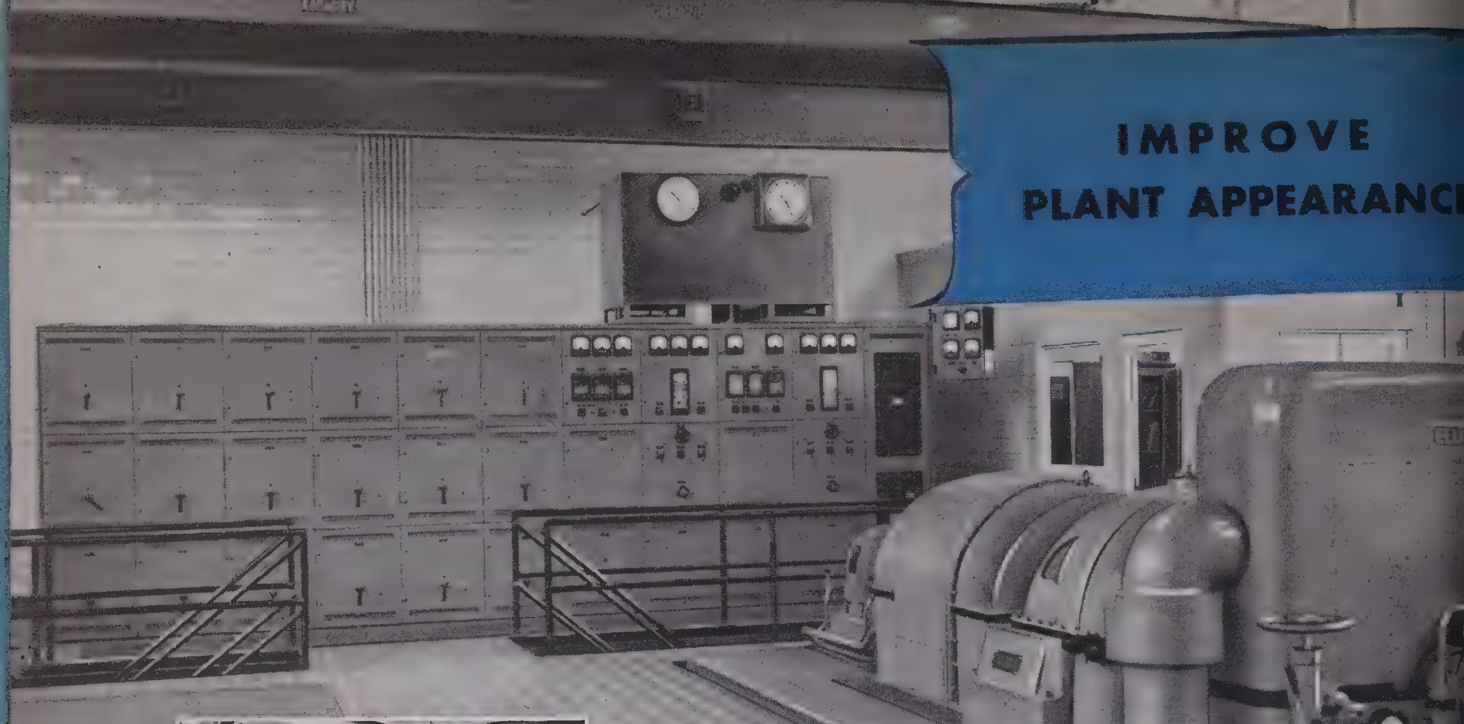
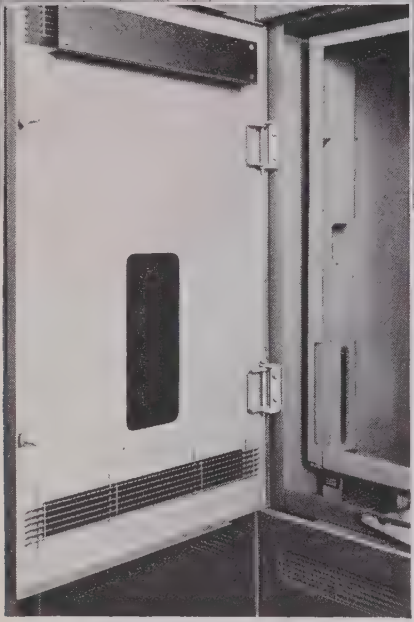
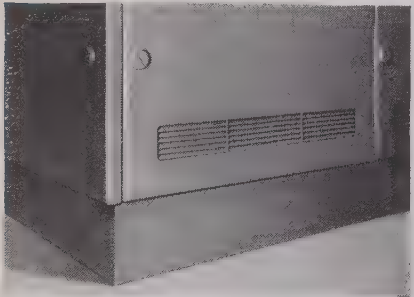


Photograph— Courtesy Falls City Brewing Co.,



All panels and doors are full-formed sheet steel. Corners are turned and welded for greater rigidity. All hinges are concealed by being mounted *inside* the enclosure. Effective grilled louvers contribute to the smooth, neat appearance of the switchboard.



Practical and attractive sturdy channel base can be bolted to the floor, or it can be inset either part-way or flush with the floor surface. Formed top trim and end panels complete the elimination of dangerous and unsightly raw metal edges.

MULTUMITE SWITCHGEAR IS ATTRACTIVE!

Note the compactness and beauty in the construction of the typical Multumite assembly above. With the exception of the breaker-operating handles and the semi-flush instruments, the exterior of the board presents a flat surface from top to base. All parts of the enclosure are full-formed from sheet steel—there are no raw metal edges. Grilled louvers and easy-to-adjust door hinges are hidden inside, adding to the pleasing appearance of the board.

The exterior finish of Multumite switchgear is an oven-baked synthetic enamel—bonderized to the metal to guarantee a permanently attractive surface.

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6003-D A complete reference guide to I-T-E 600 V Switchgear assemblies. Contains dimension information on I-T-E Multumite, and helpful facts for specifying and ordering complete switchgear installations.

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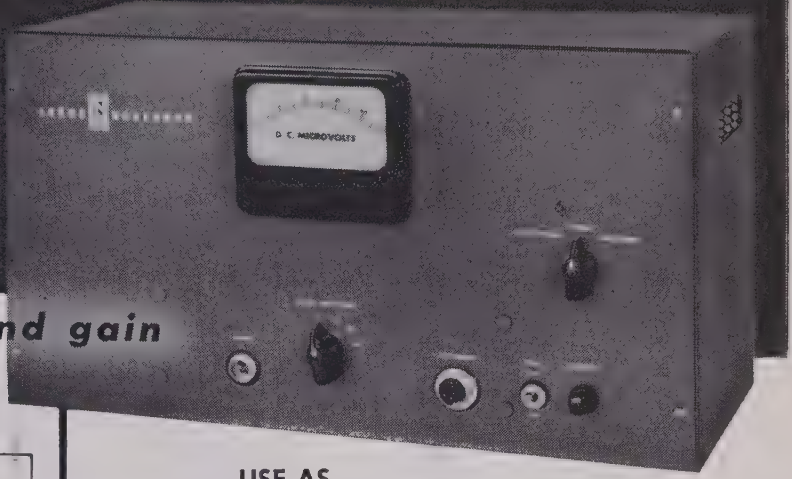
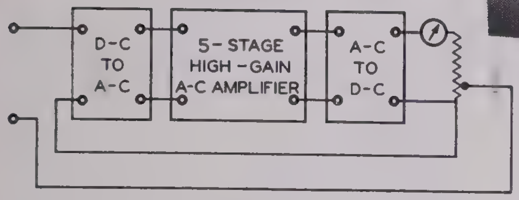


stabilized for zero and gain



Voltage-balance feedback (above) and current-balance feedback stabilize gain . . . provide virtual null balance.

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MICROVOLT UNIT Catalog No. 9835	MICRO-MICRO-AMPERE UNIT Catalog No. 9836
FULL SCALE RANGES WITH BUILT-IN 4″ METERS	
0 to 50 or —25 to +25 Microvolts; scale multipliers: 1,2,4,10, 20,40	0 to 1000 or —500 to +500 Micro-Micro-amps; scale multipliers: 1, 2, 5, 10, 20, 50, 100, 200, 500, 1000, 2000
ACCURACY	
Of amplifier: ±0.4% of reading ±0.5 Microvolt; Of meter: ±1%	Of amplifier: ±0.5 to 0.8%* of reading ±20 Micro-Micro-amps; Of meter; ±1%
STABILITY	
Zero and Gain stabilized automatically. No trimmer controls required.	
*SOURCE RESISTANCE	
Up to 10,000 ohms.	0.1 megohm or more.
RESPONSE TIME	
2 to 3* sec.	2 to 3* sec.
OUTPUT	
For full scale input on any range: 10 millivolts at output impedance of 500 ohms for null recorder; 1 volt for 20,000-ohm external meter.	

Front panel fits standard 19″ relay rack.

*Accuracy and Response Time depend on Source Resistance.

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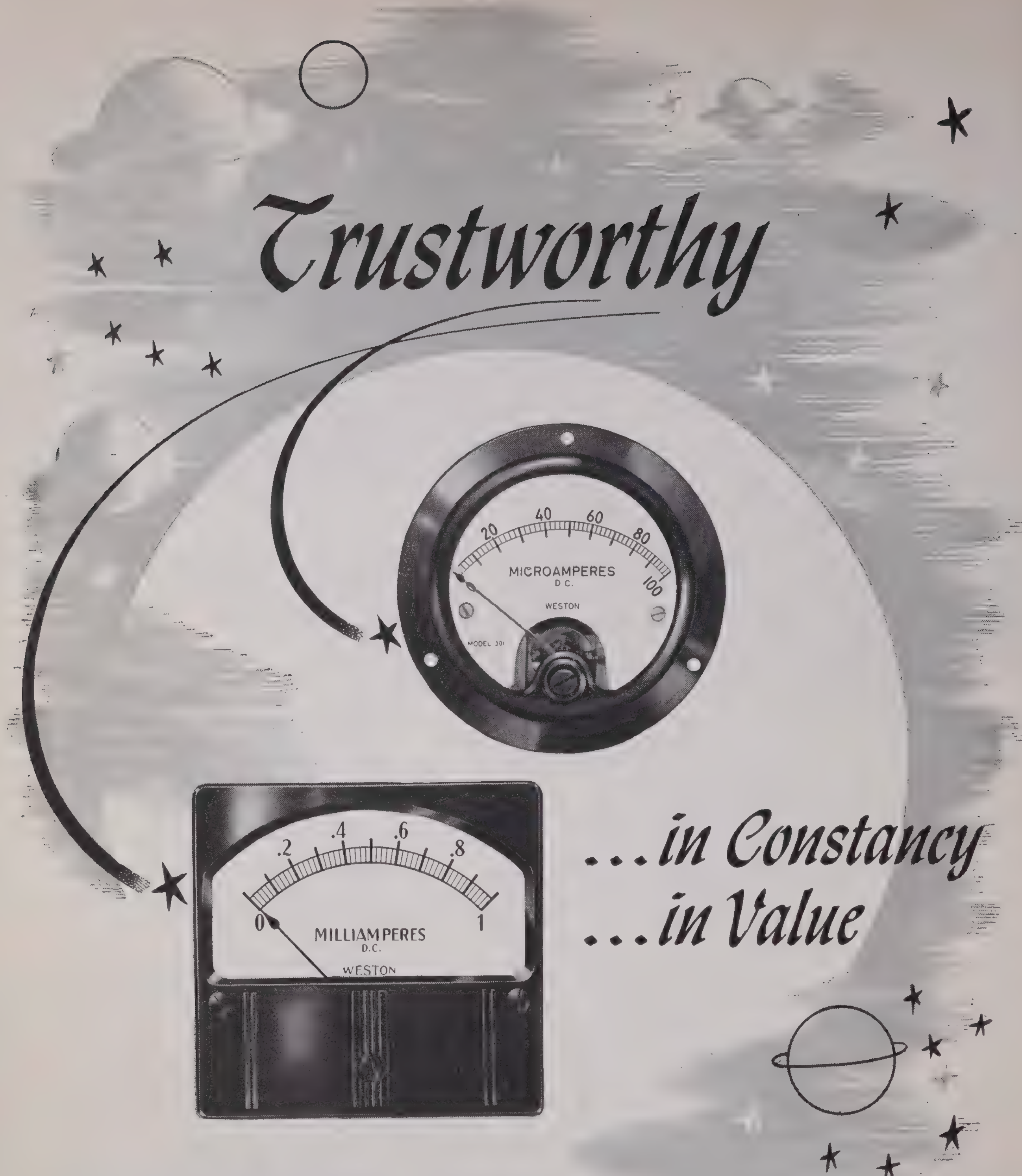

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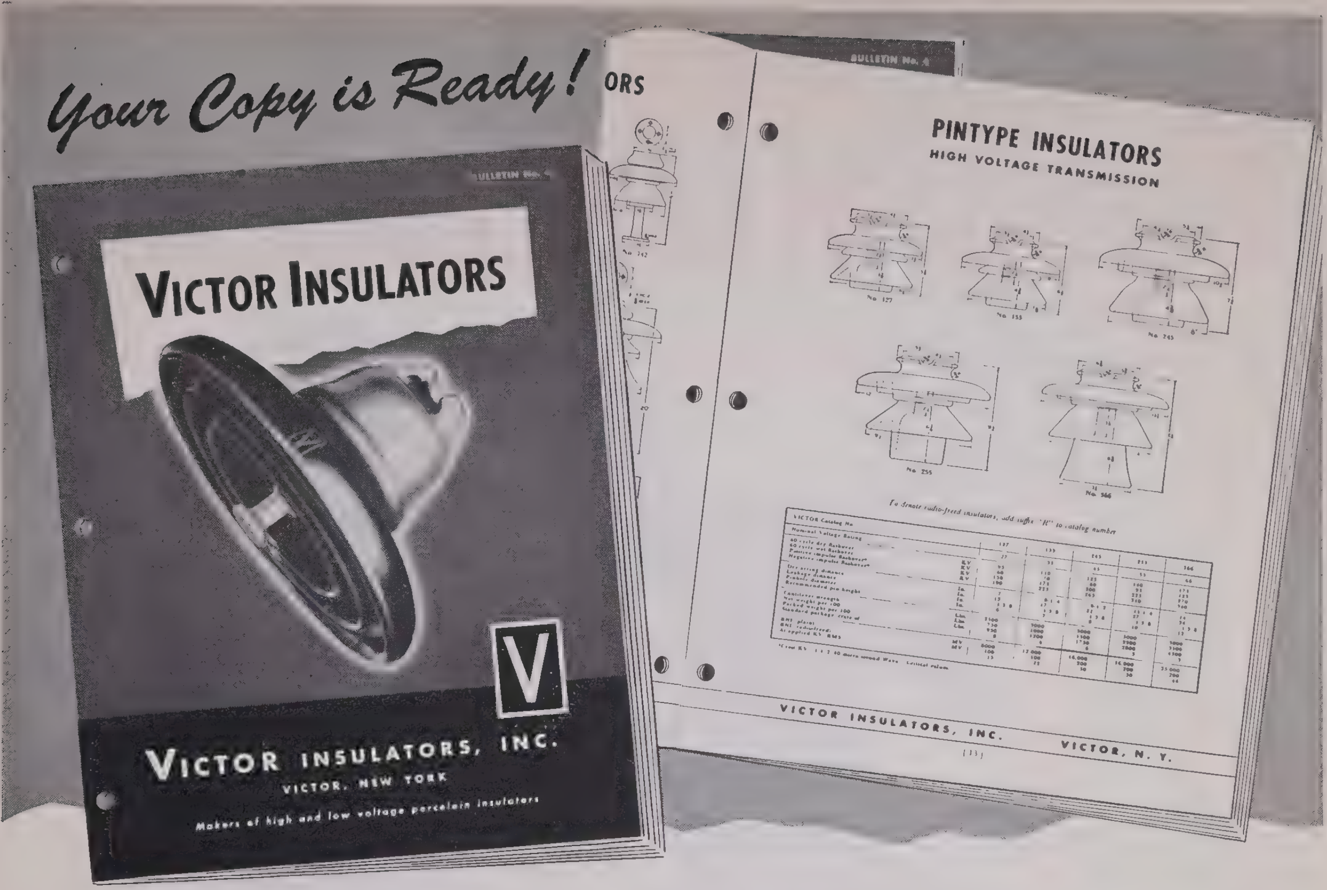

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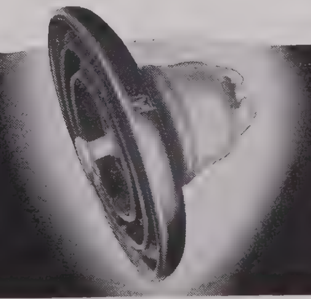

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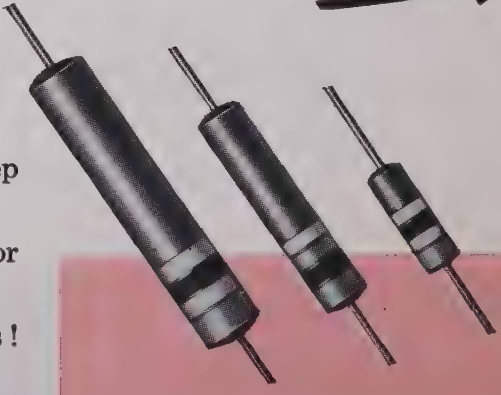

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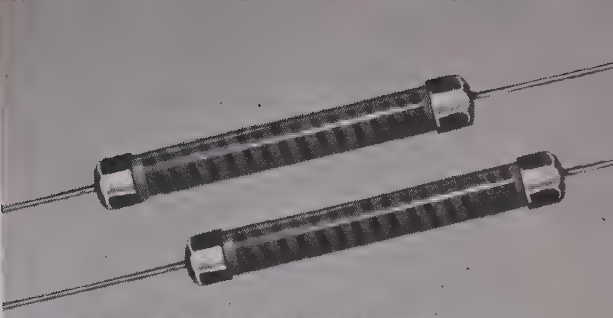

IN HIGH VOLTAGE APPLICATIONS where high resistance and power are required, Type MVX high ohmic, high voltage resistors afford exceptional stability. Construction is similar to that of Type MV, but distinctive terminal permits mounting through a hole in mounting block of insulating material without terminal interference. Long resistance path permits use of high voltage on resistor while keeping voltage per unit length of path comparatively low. Check coupon for Catalog G-2.

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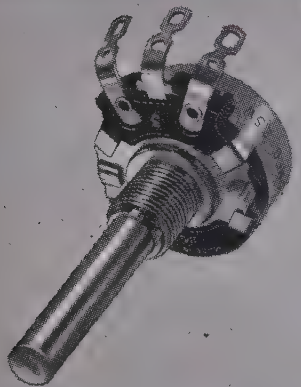

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SALES ENGINEER, 28–35, electrical graduate, to sell electrical equipment used in the transmission of electrical power. Any experience with a power company or electrical equipment manufacturer desirable. Training in Midwest from three to twelve months. Salary, $4000–$6000 a year. Location, New York, N. Y. Y-3476.

RELAY ENGINEER, up to and around 60, electrical engineer, with eight to ten years' experience in application, installation, manufacture or development of electrical distribution systems, relays. Will take charge of problems, selection and installation on utilities power system. May accept utilities man well grounded in relay engineering who has retired or otherwise separated from utilities work. Salary, about $6000 a year. Location, Illinois. Y-3547-R-6416.

ENGINEERS. (a) Design Engineer, electrical graduate, with fifteen years' or more experience in design and layout of rolling mill electrical facilities, to supervise design of motor drives, controls, etc. Salary, $8000–$9000 a year. (b) Electrical Designer, electrical graduate, with at least eight years' experience in rolling mill practice, to design and lay out power equipment. Salary, $6000–$7000 a year. Location, Pennsylvania. Y-3558.

ASSOCIATE PROFESSOR in electrical engineering, Doctor's degree, and at least five years' teaching experience; should also have had experience in industry. Should have published books or articles and should be prominently recognized in the field of electrical engineering. Salary, $4800–$6800 a year. Location, Michigan. Y-3560.

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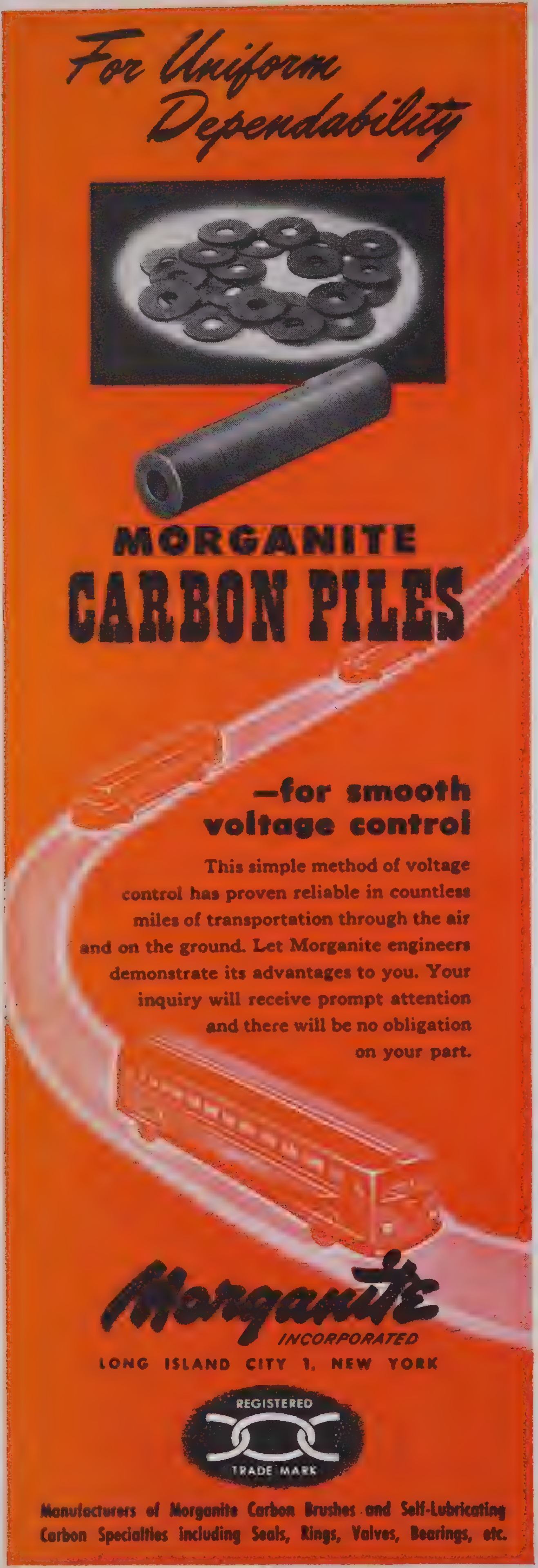

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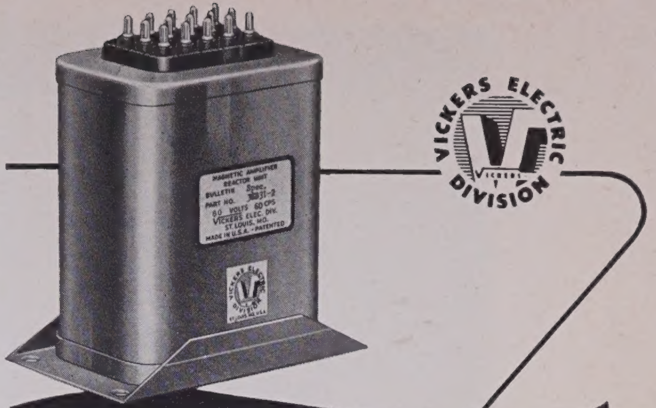

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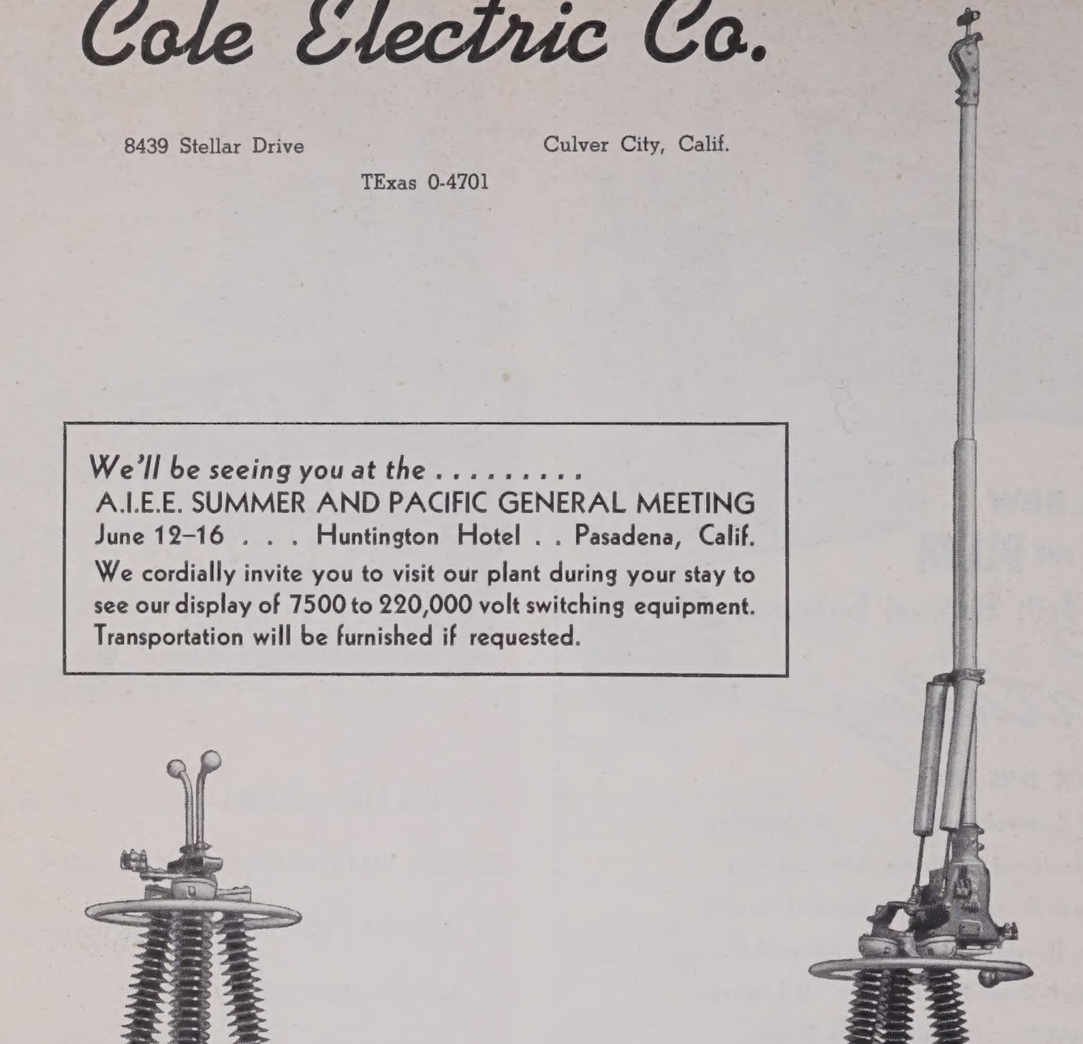

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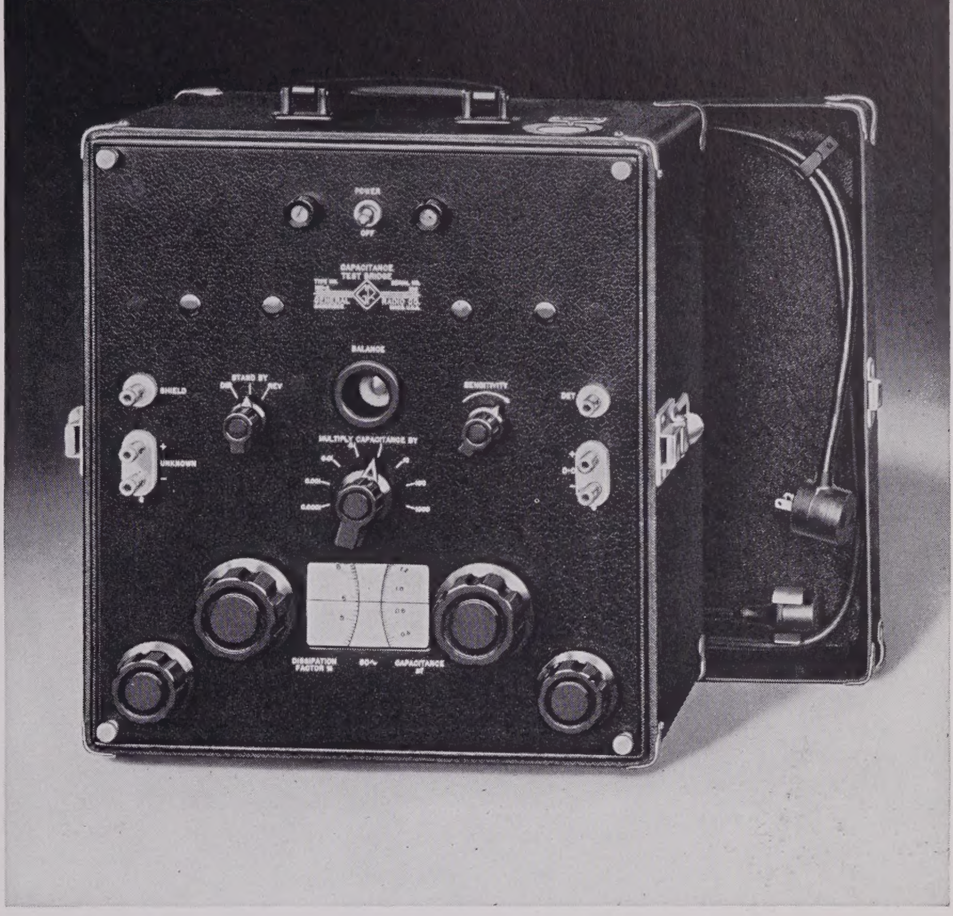

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